MULTIPLE MODEL ADAPTIVE ESTIMATION AND CONTROL REDISTRIBUTION PERFORMANCE ON THE VISTA F-16 DURING PARTIAL ACTUATOR IMPAIRMENTS

VOLUME II

DEPARTMENT OF THE AIR FORCE
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AFIT/GE/ENG/97D-23

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VOLUME II

THESIS

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AFIT/GE/ENG/97D-23

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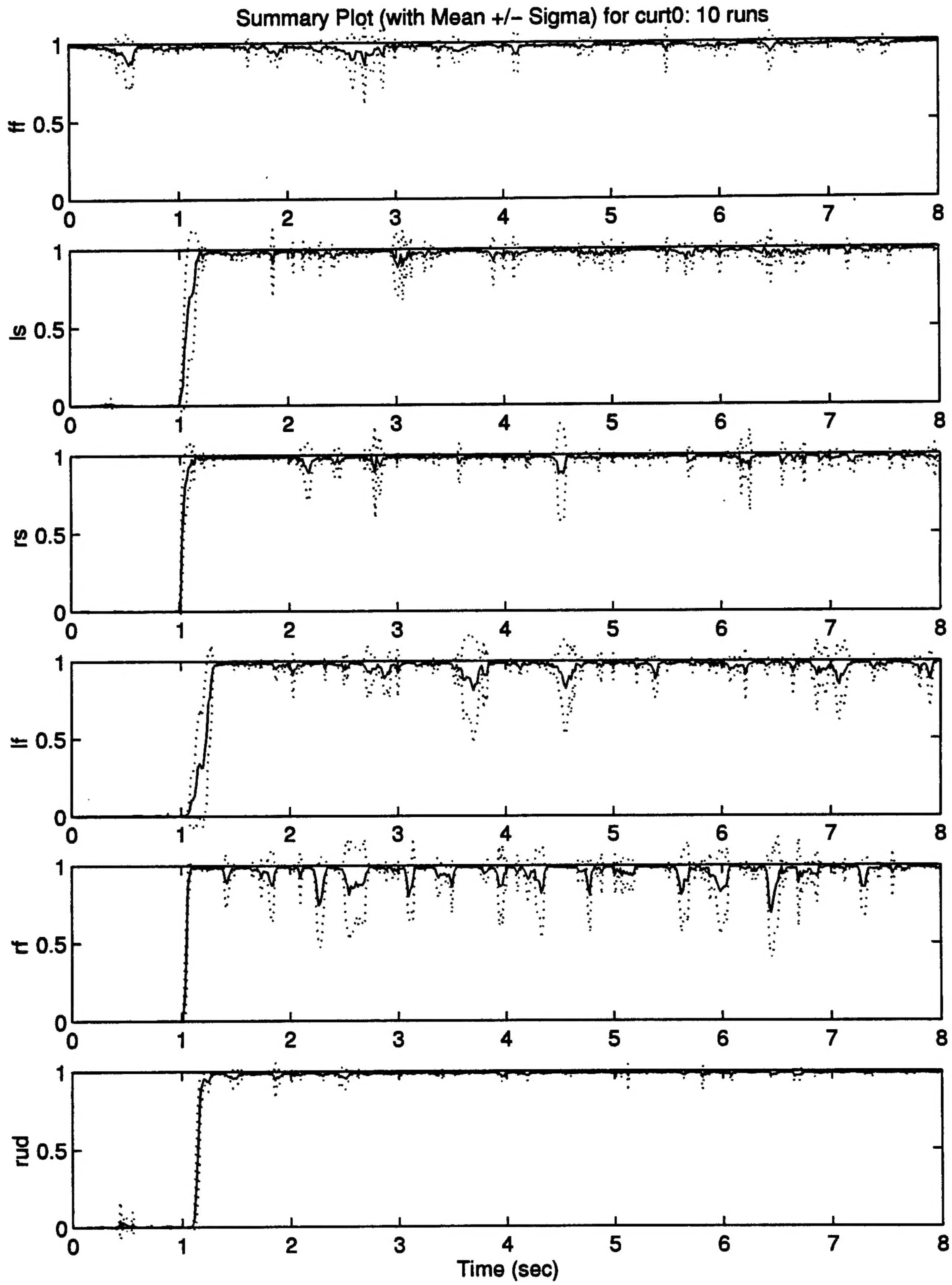
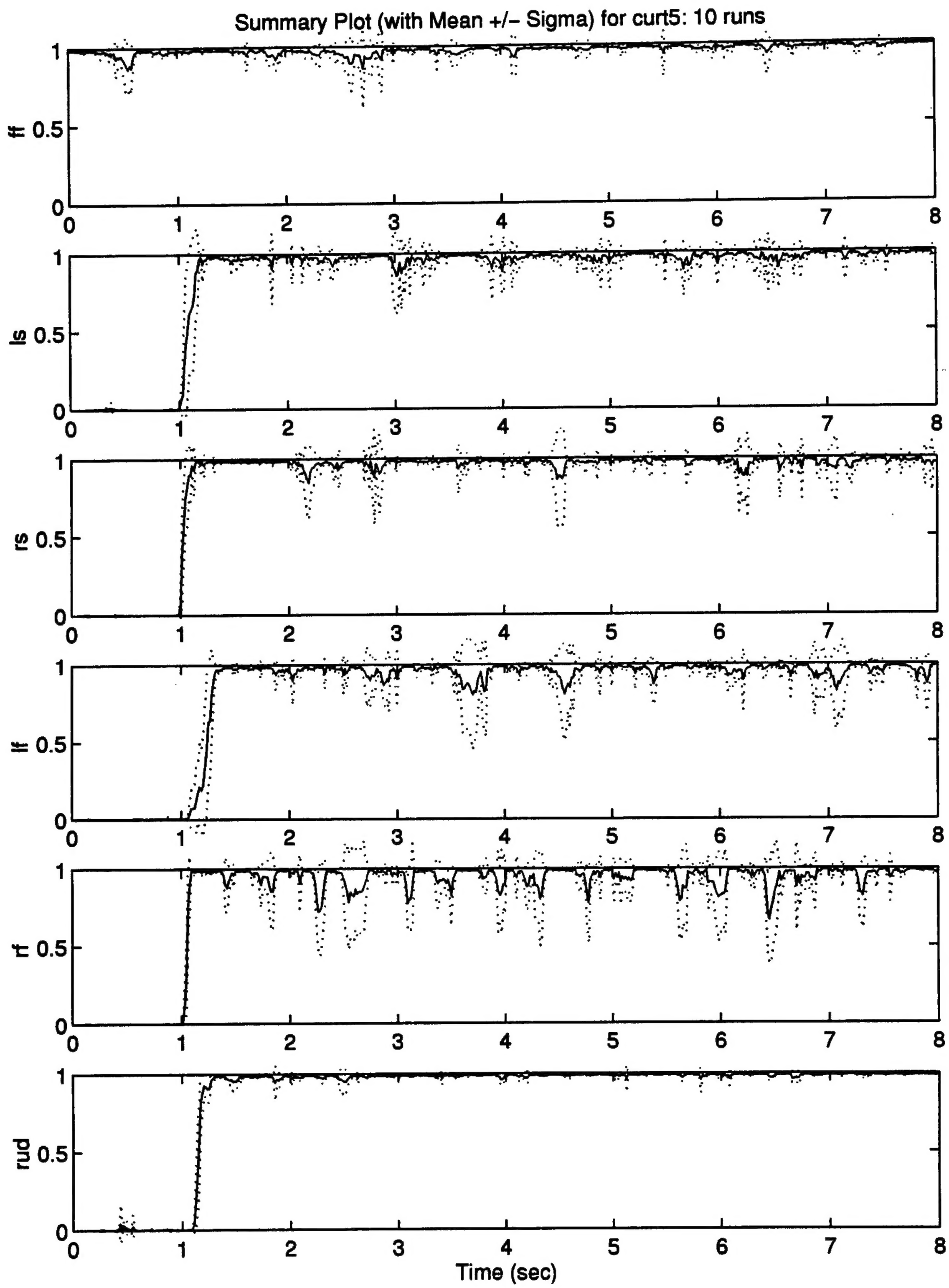
This section contains the Probability Summary Plots specified in Section 4.5.1 which were used to compile Table 4-1. The following table is a guide to the plots found in this section. The leftmost column lists the MMAE probability channels that are plotted (in parentheses), together with their meanings. The **Boldface** entries are the *plot data* titles (which were used for data indexing purposes) found within the full title at the top of each summary plot, and are listed in the order, from left to right in the bottom row of the table, that the plots are found in this section. As an example, the Probability Summary Plot for the partial actuator impairment cases with ε = .05 (95% actuator impairment cases) is titled: "Summary Plot (with Mean +/- Sigma) for curt5: 10 runs"

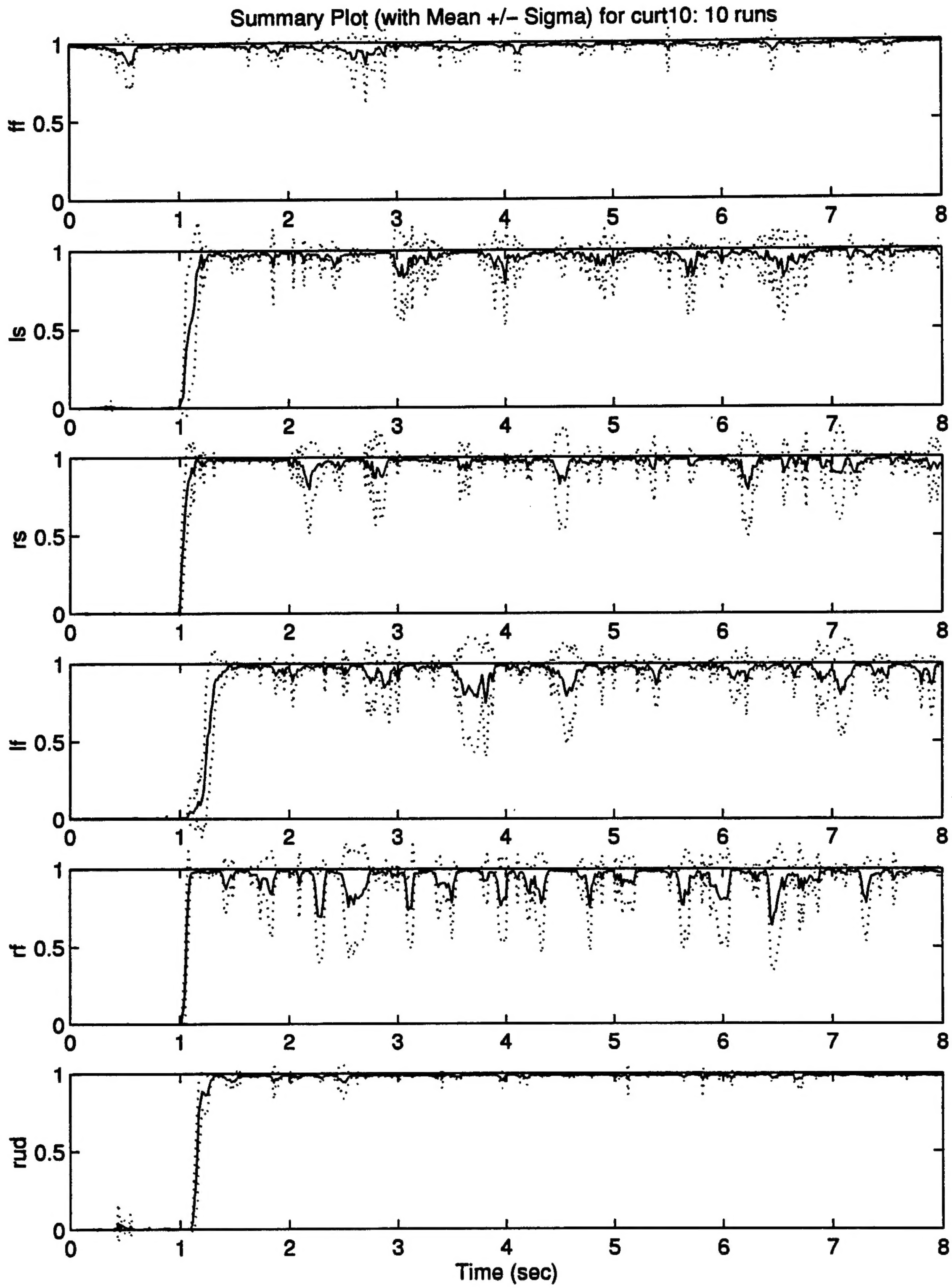
PROBABILITY SUMMARY PLOTS FOR SINGLE CONTROL SURFACE PARTIAL IMPAIRMENTS: NO RECONFIGURATION, NO MANEUVER, DITHER 'ON'							
Control Surface	Actuator Effectiveness Factor, ε , at 1 second (0 = totally failed, 1= fully functional)						
Fully Functional (ff)							
Left Stabilator (ls)	0	.05	.1	.15	.25	.50	.75
Right Stabilator (rs)	0	.05	.1	.15	.25	.50	.75
Left Flaperon (lf)	0	.05	.1	.15	.25	.50	.75
Right Flaperon (rf)	0	.05	.1	.15	.25	.50	.75
Rudder (rud)	0	.05	.1	.15	.25	.50	.75
Summary Plot Title	**curt0**	**curt5**	**curt10**	**curt15**	**curt25**	**curt50**	**curt75**

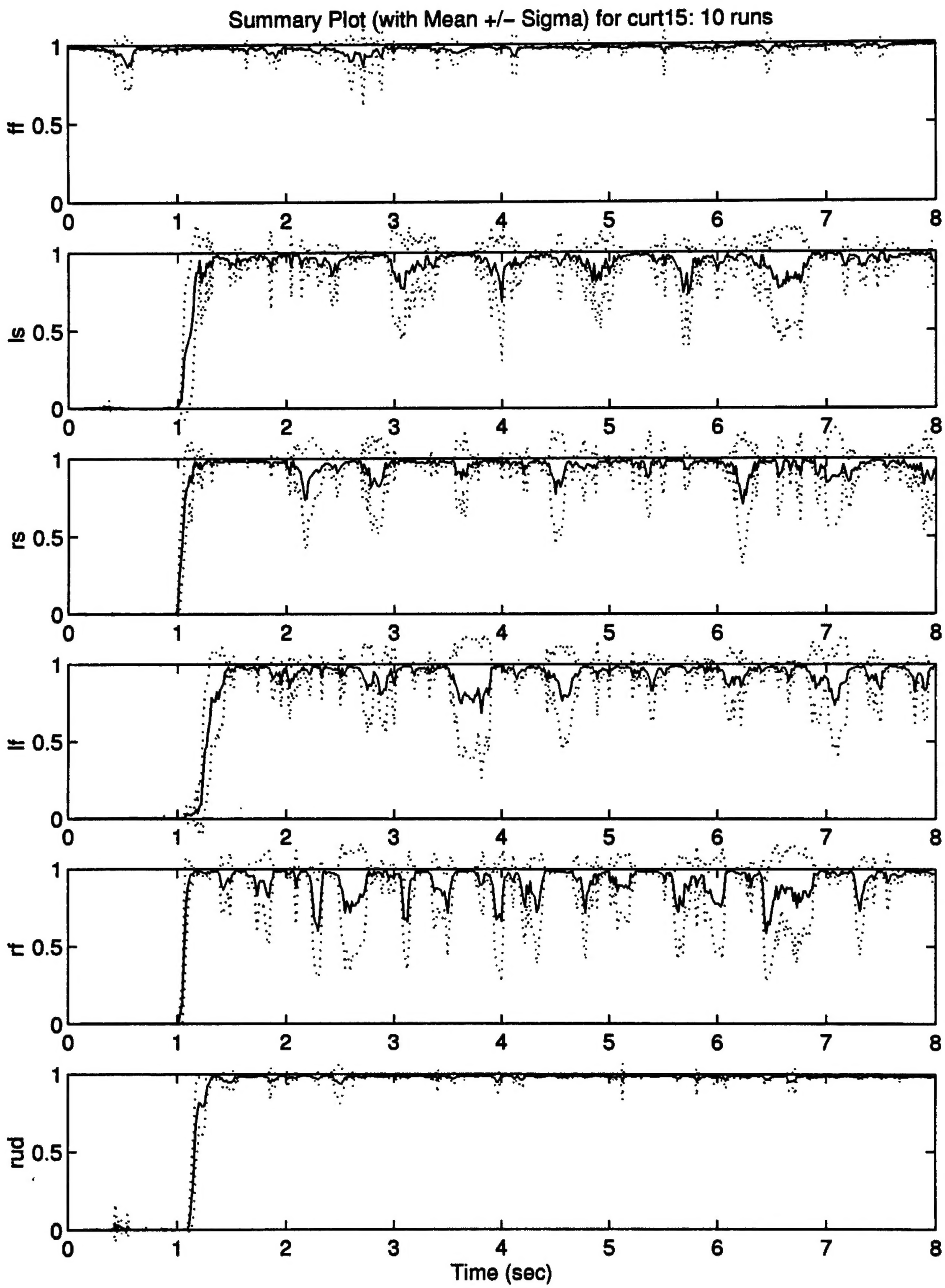


Summary Plot (with Mean +/- Sigma) for curt0: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)

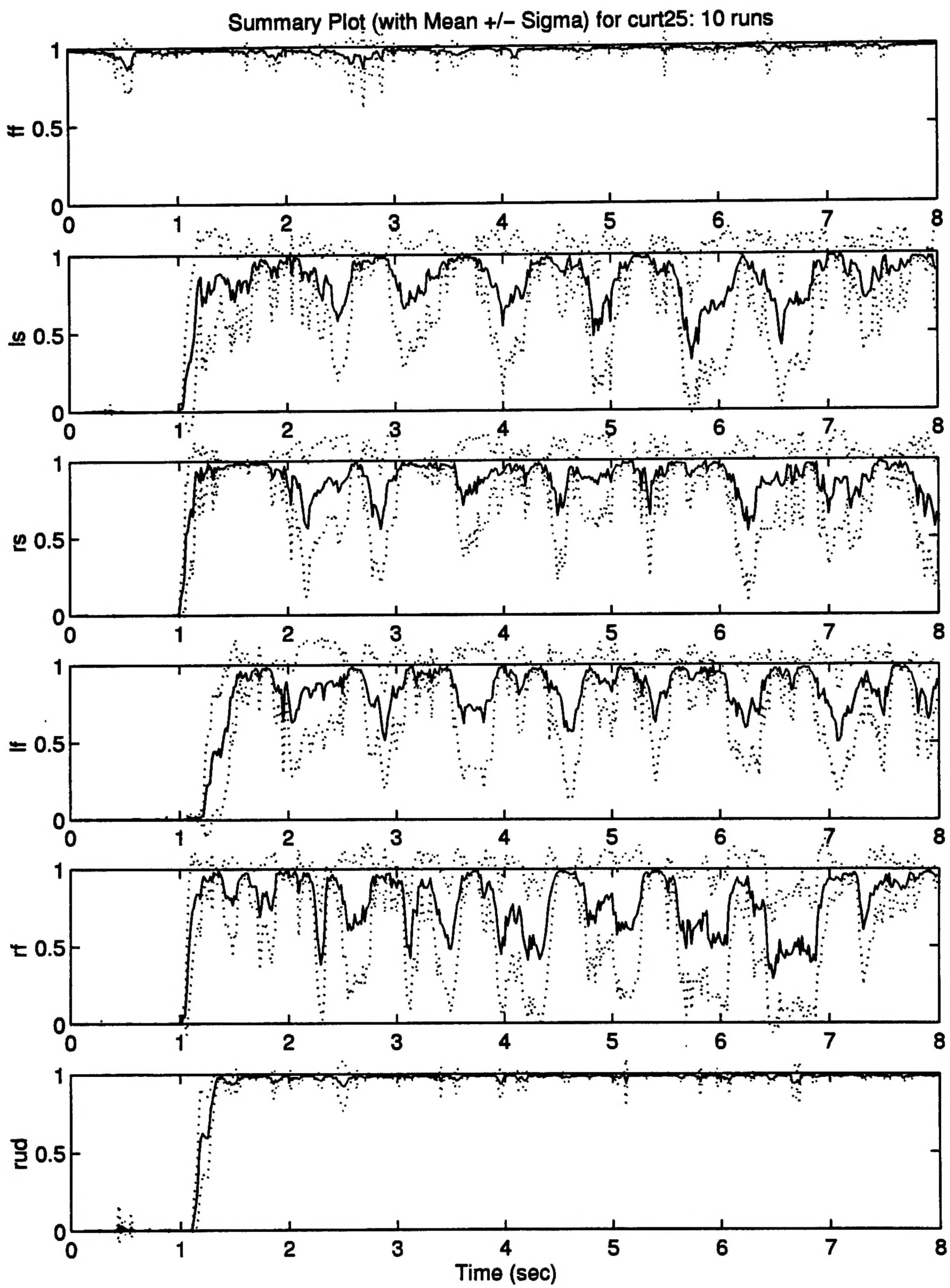


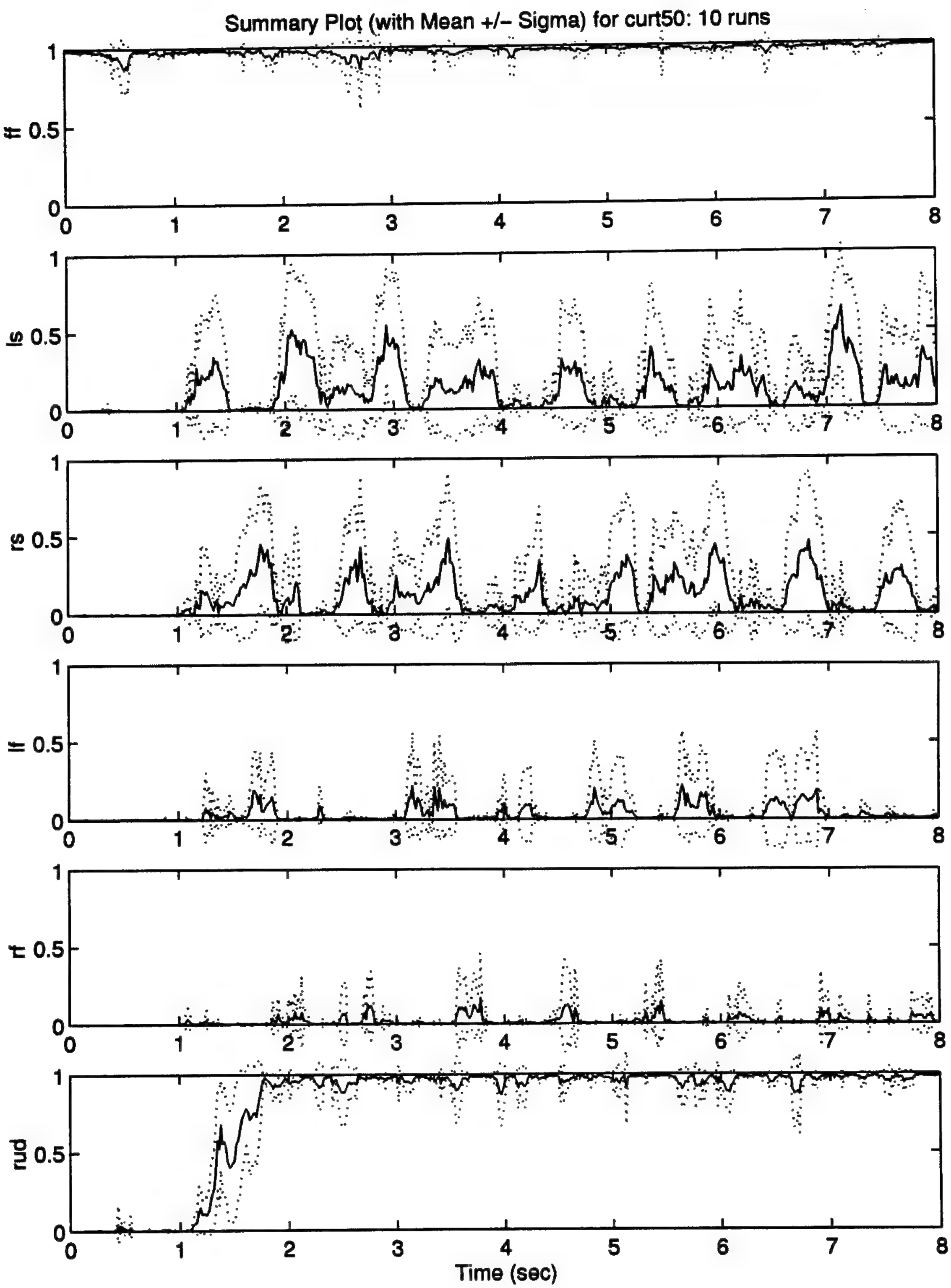
Summary Plot (with Mean +/- Sigma) for curt5: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)

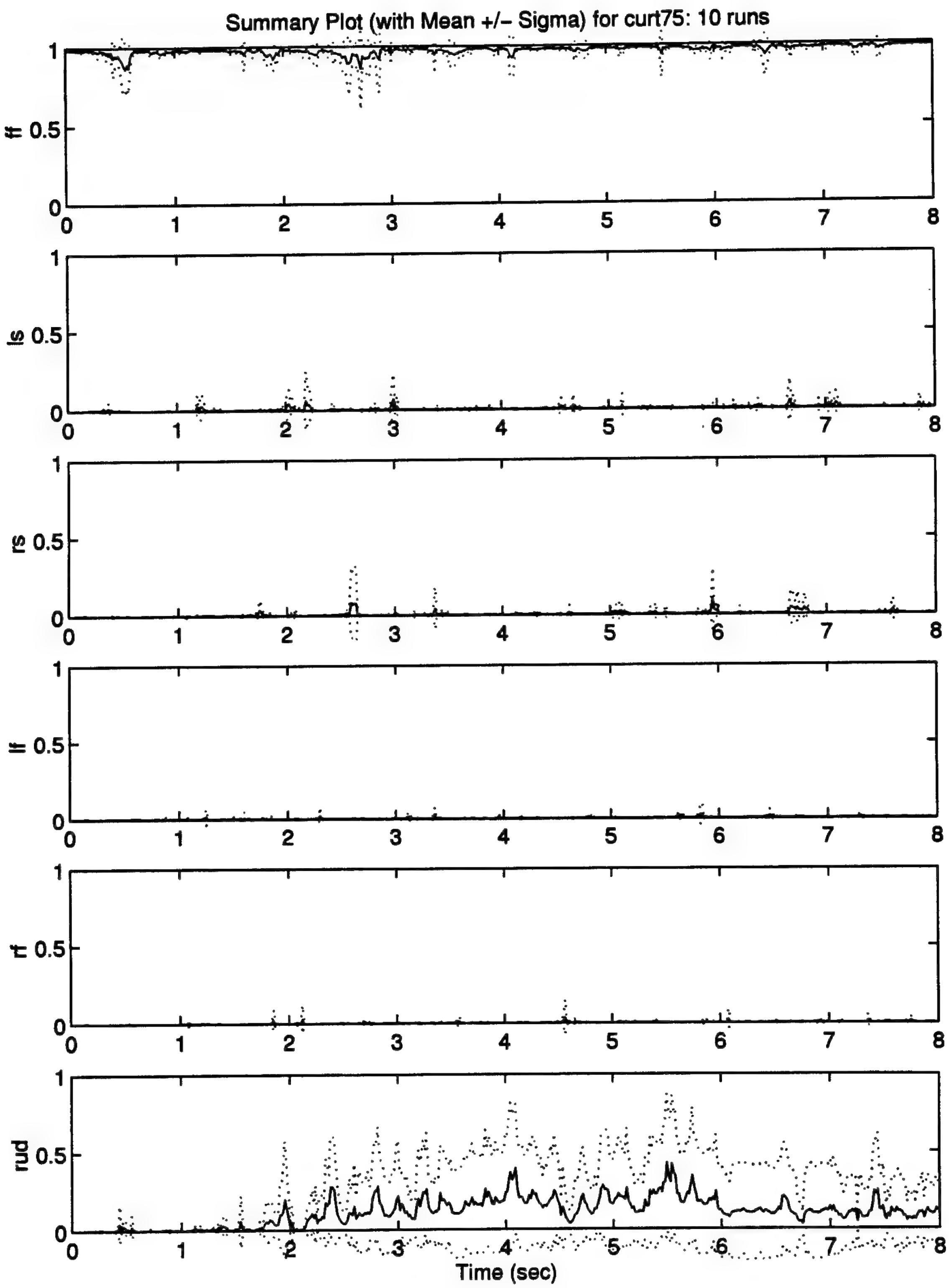

Summary Plot (with Mean +/- Sigma) for curt10: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)



Summary Plot (with Mean +/- Sigma) for curt15: 10 runs
ff
ls
rs
lf
rf
rud
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec)


Summary Plot (with Mean +/- Sigma) for curt25: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)


Summary Plot (with Mean +/- Sigma) for curt50: 10 runs
ff
ls
rs
lf
rf
rud
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec)



Summary Plot (with Mean +/- Sigma) for curt75: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)

Appendix M: An Alternative Control Reconfiguration Method

For Cases of Partial Actuator Impairment

In cases of partial actuator impairment ($0<\varepsilon<1$), the direct pseudoinverse calculation (Equation (3-35)) is equal to the true inverse calculation: $\mathbf{F}_{ai}^{-1}$. The true inverse calculation will command the partially impaired actuator to $1/\varepsilon$ times the original command, and, as ε assumes values less than 0.5 (50% actuator failure or greater) this may cause actuators to be commanded to rate and/or position saturations. Maybeck [37] has suggested an alternative to computing and using $\mathbf{F}_{ai}^{-1}$ (Section 3.9.2), in cases of partial impairments, which would simplify redistribution calculations and *perhaps* prevent rate and position saturations of remaining actuators.

The alternative to using the true inverse calculation, $\mathbf{F}_{ai}^{-1}$, for *partially* impaired actuators is to use a variant of the pre-packed $\mathbf{D}_{ai}$ matrix (Equation (3-37)) for *totally* failed actuators. Given a partial impairment of the i^{th} actuator such that its effectiveness is ε, the procedure is to multiply all j elements ($j \neq i$) in column 'i' of $\mathbf{D}_{ai}$ by ε. The command to the impaired actuator ($j = i$) is equal to 1.0, and all *other* columns of "$\mathbf{D}_{ai}$ variant" contain ones on the diagonal. It can be proven [49] that this alternative method satisfies Equation (3-32). An example is given for the case of a 70% left stabilator (i=1) actuator impairment (actuator effectiveness, ε =.3). The desired condition is expressed by Equations (3-30) and (3-32):

$$\mathbf{B}_{fail}\mathbf{u}_r \approx \mathbf{Bu} \tag{3-30}$$

$$\mathbf{u}_r = \mathbf{D}_{ai}\mathbf{u} \tag{3-32}$$

For the impairment case specified, Equation (3-36) applies and results in:

$$\mathbf{D}_{ai} = \mathbf{F}_{ai}^{-1} = \begin{bmatrix} 3.3 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

The alternative method for this case is to take the fully-failed Control Reconfiguration matrix, $\mathbf{D}_{al}$, for the left stabilator:

$$\mathbf{D}_{al} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ +0.906 & 0 & 1 & 0 & 0 \\ -0.906 & 0 & 0 & 1 & 0 \\ +0.786 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Entry (1,1) is set equal to 1.0 (to generate a full command to the left stabilator, to which you anticipate a response with 70% effectiveness) and all other entries in the first column (column i = 1) are multiplied by 0.3 ($\varepsilon = .3$), to distribute the required additional 30% effectiveness among the unfailed actuators, to yield:

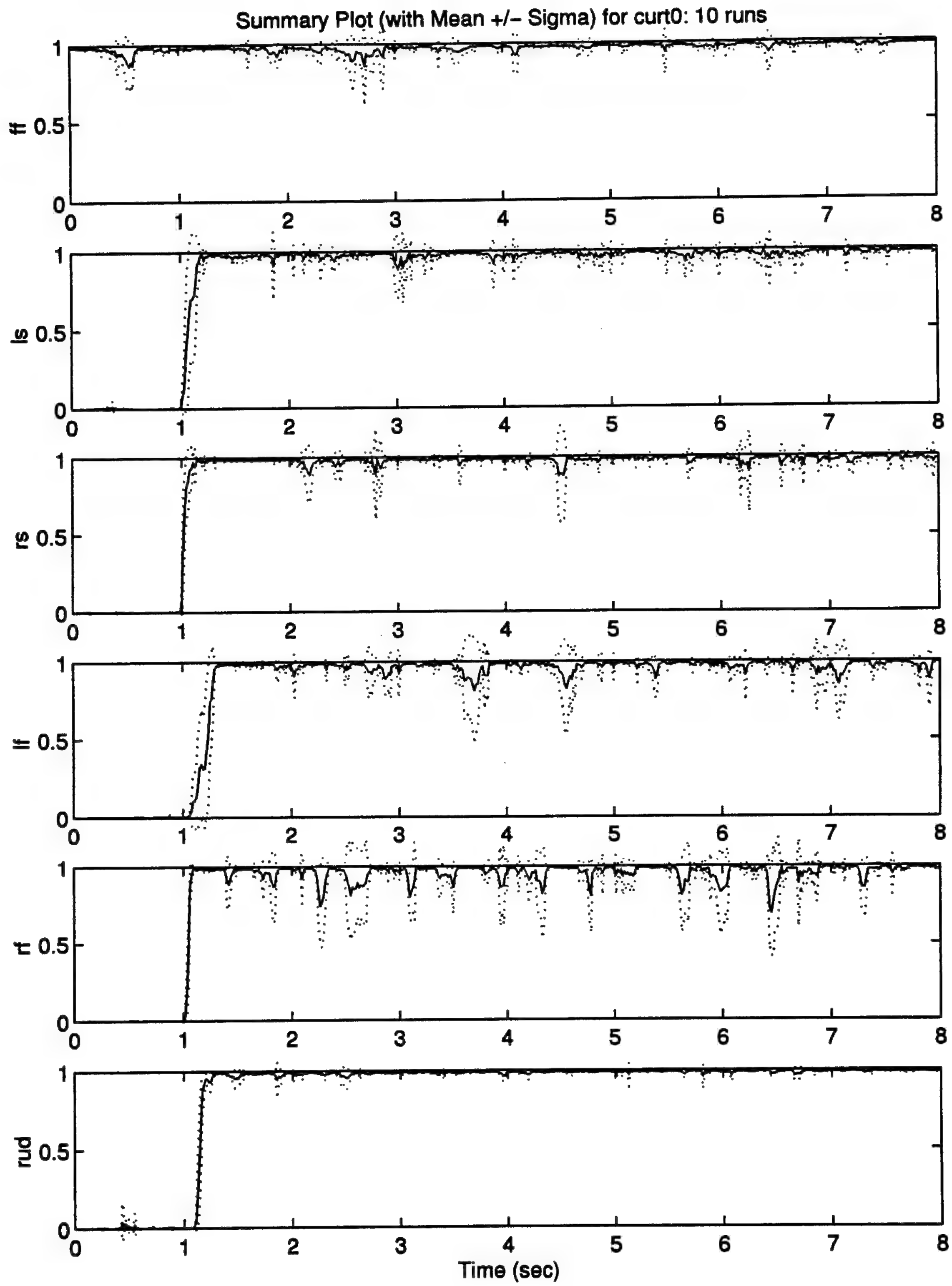
$$\mathbf{D}_{al\,variant} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0.3 & 1 & 0 & 0 & 0 \\ +0.2718 & 0 & 1 & 0 & 0 \\ -0.2718 & 0 & 0 & 1 & 0 \\ +0.2358 & 0 & 0 & 0 & 1 \end{bmatrix}$$

This result inserted into Equation (3-32) satisfies Equation (3-30), and may prevent the left stabilator from being "overdriven" into rate or position saturation.

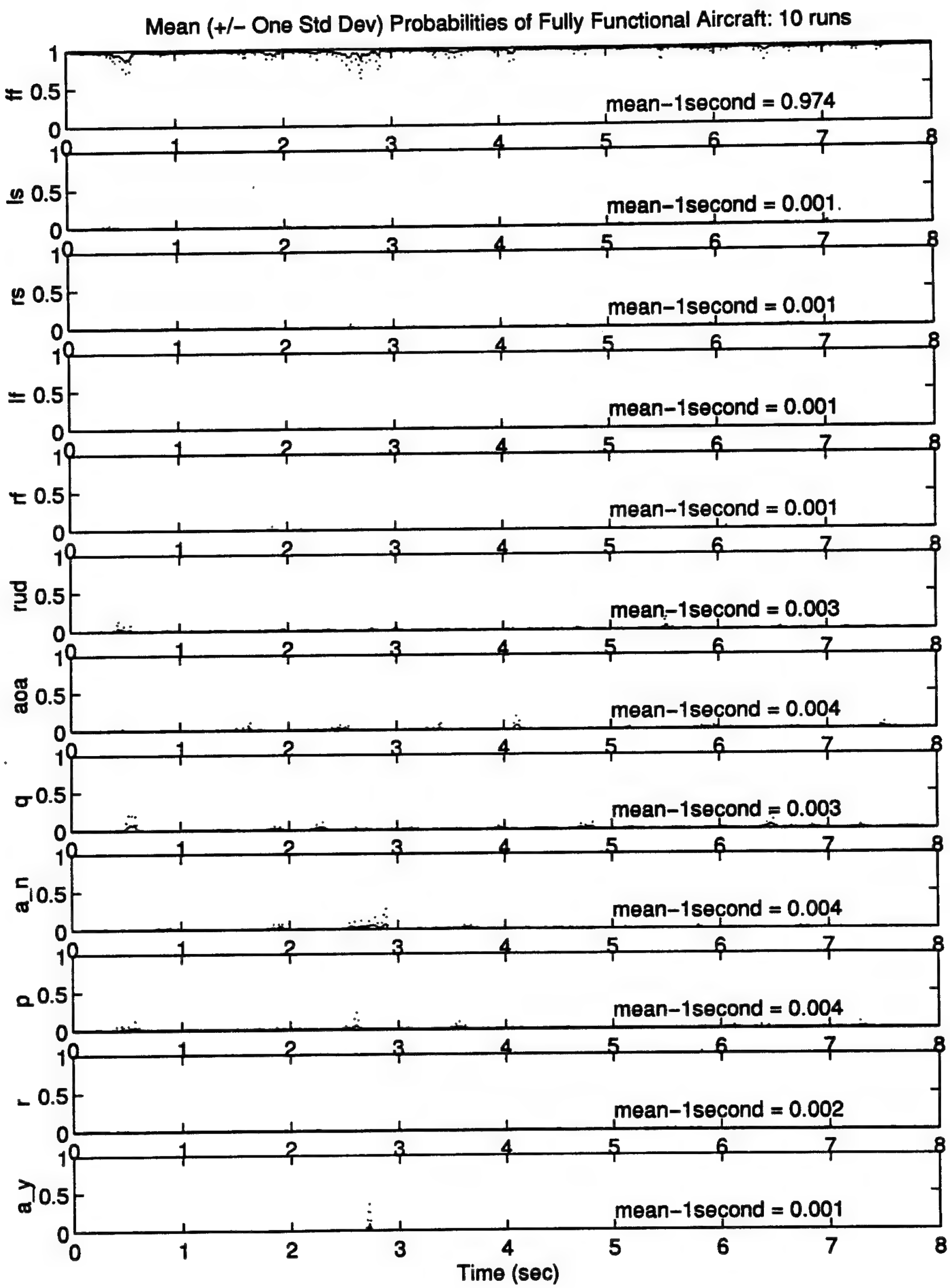
Appendix A.1: Single Total Actuator Impairments ($\varepsilon = 0$), Control Redistribution 'OFF', Dither 'ON', No Maneuvers

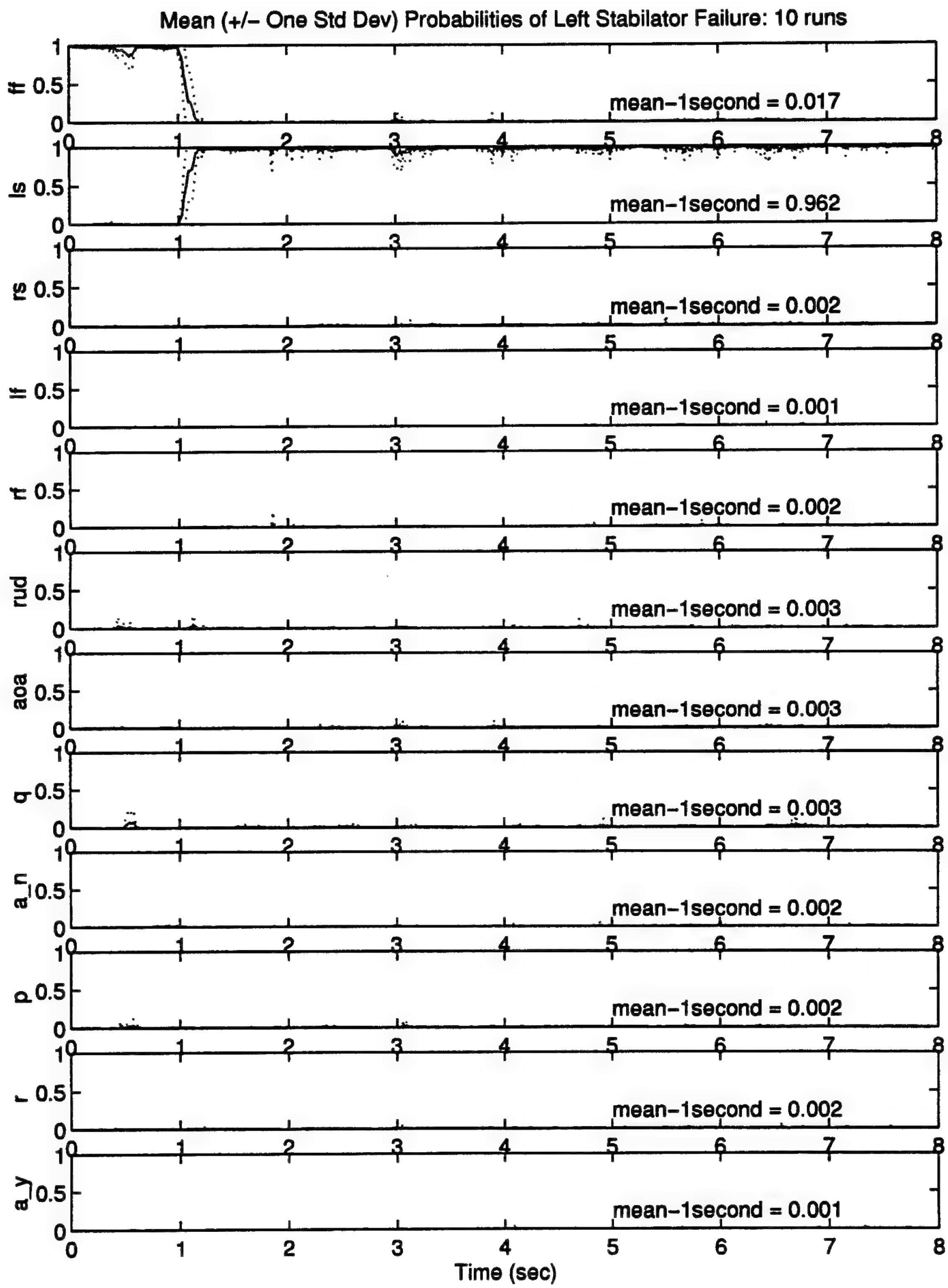
This appendix contains the Probability Summary Plot and individual probability plots for cases of single, total (100%) actuator impairments, without aircraft maneuvering or Control Reconfiguration (Redistribution), but with control dithering (Sections 4.5 and 4.11.1). The following table reviews the MMAE channel abbreviations found on the plots, together with their meanings:

MMAE Channel Abbreviation	Filter Hypothesis (Actuators)	MMAE Channel Abbreviation	Filter Hypothesis (Sensors)
ff	Fully Functional	aoa	Angle-of-Attack
ls	Left Stabilator	q	Pitch Rate
rs	Right Stabilator	a_n	Normal Acceleration
lf	Left Flaperon	p	Roll Rate
rf	Right Flaperon	r	Yaw Rate
rud	Rudder	a_y	Lateral Acceleration

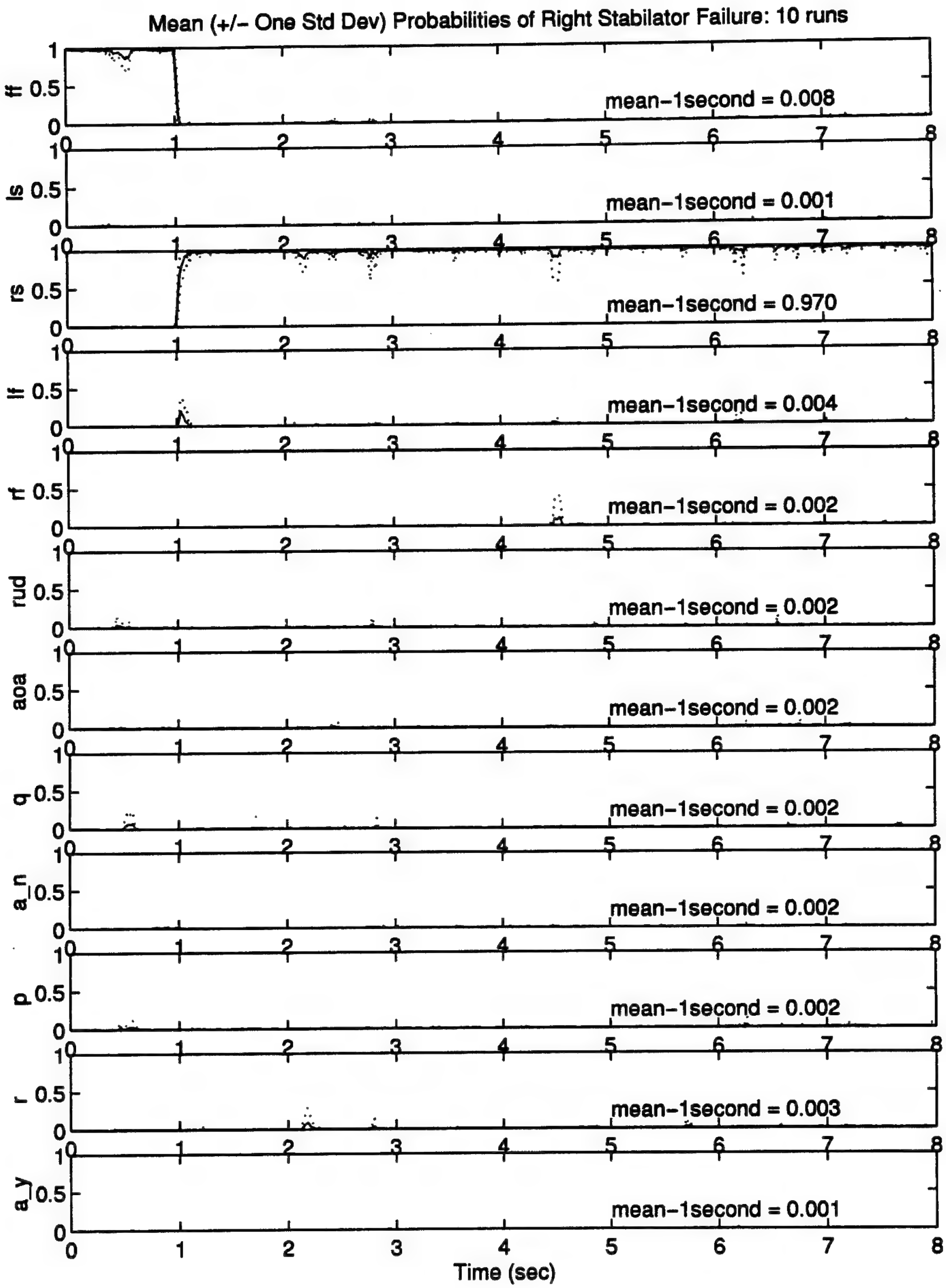


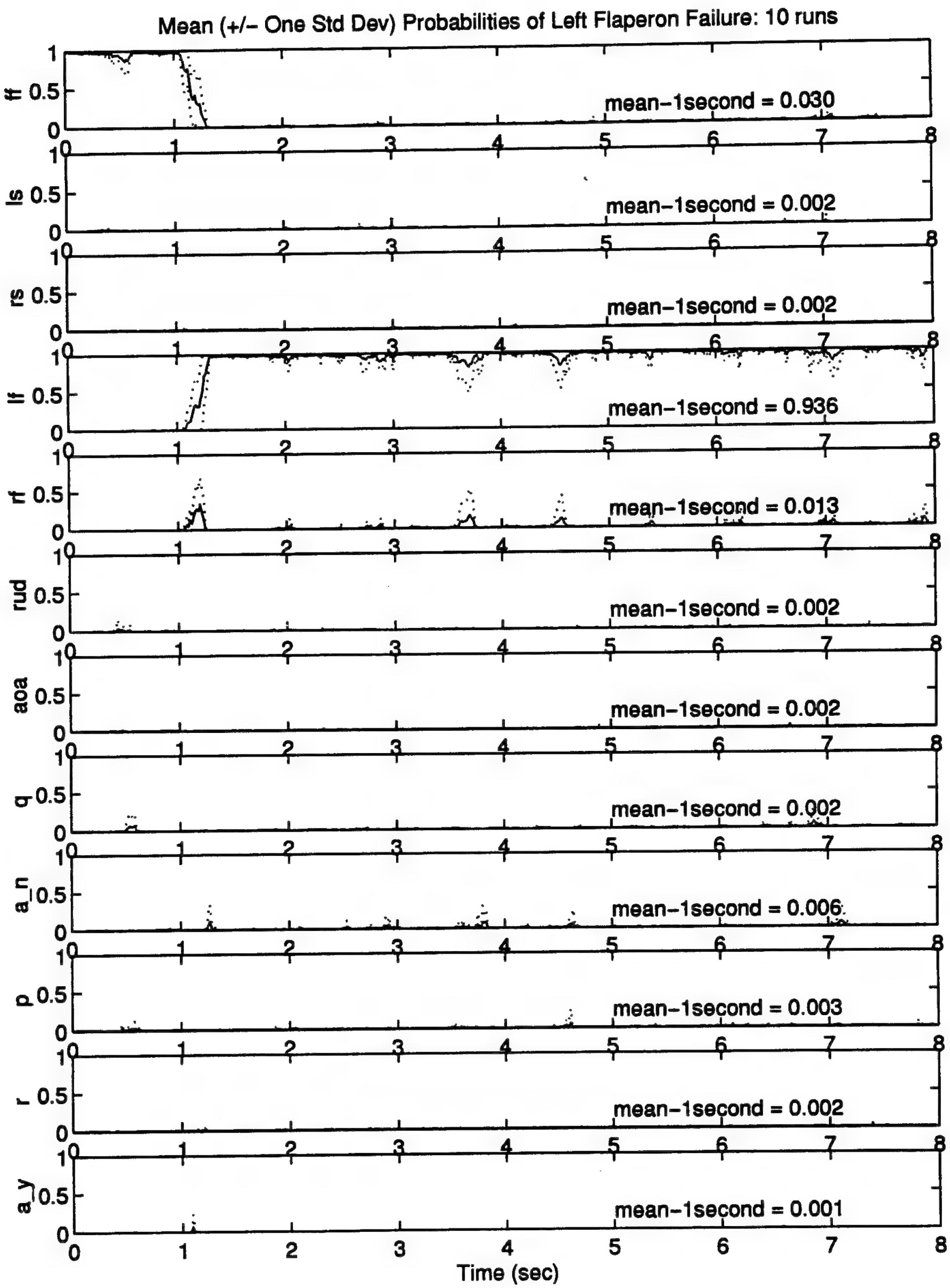
Summary Plot (with Mean +/- Sigma) for curt0: 10 runs
ff
ls
rs
lf
rf
rud
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec)

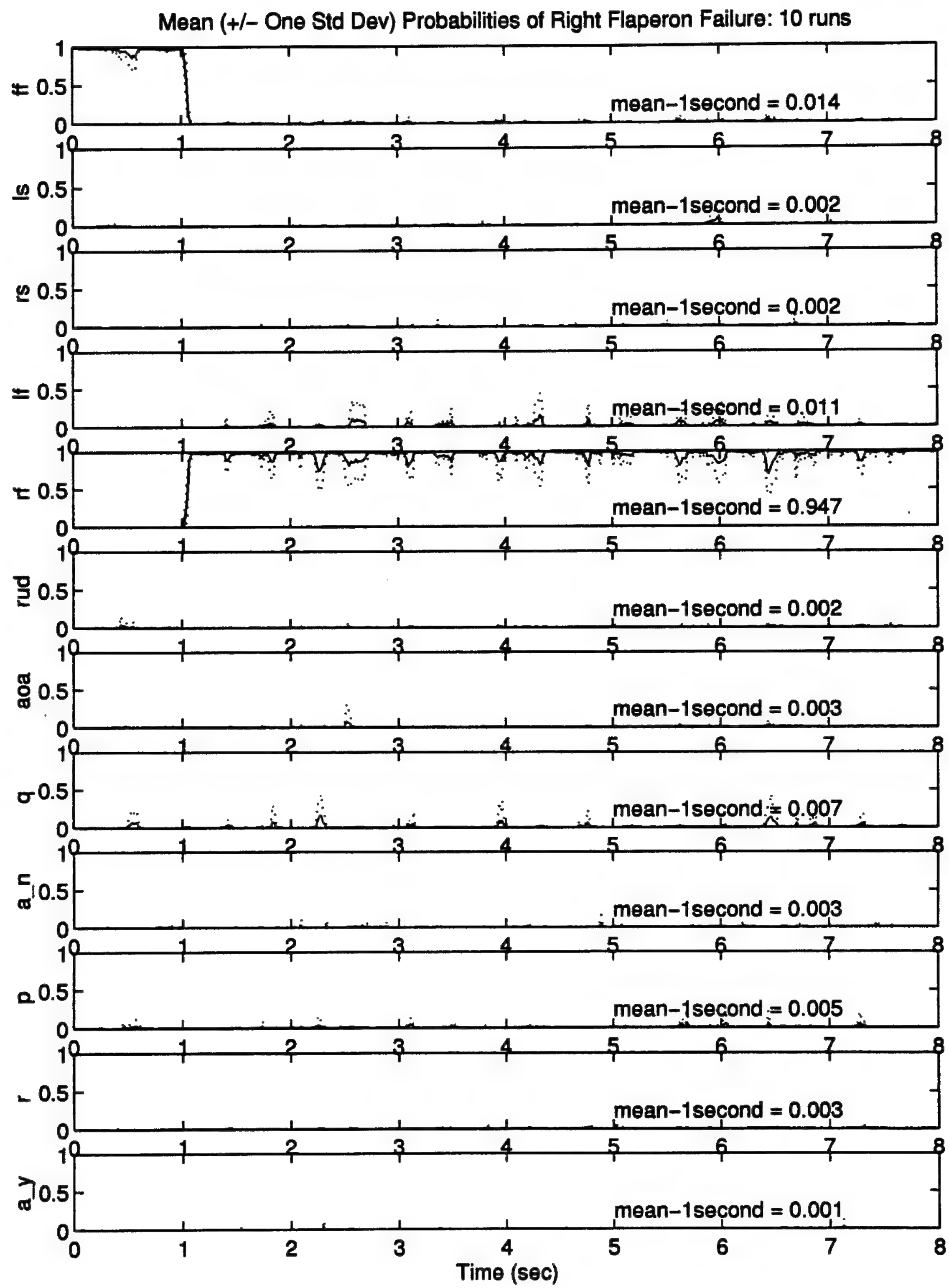

Mean (+/- One Std Dev) Probabilities of Fully Functional Aircraft: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
mean-1second = 0.974
mean-1second = 0.001
mean-1second = 0.001
mean-1second = 0.001
mean-1second = 0.001
mean-1second = 0.003
mean-1second = 0.004
mean-1second = 0.003
mean-1second = 0.004
mean-1second = 0.004
mean-1second = 0.002
mean-1second = 0.001
Time (sec)



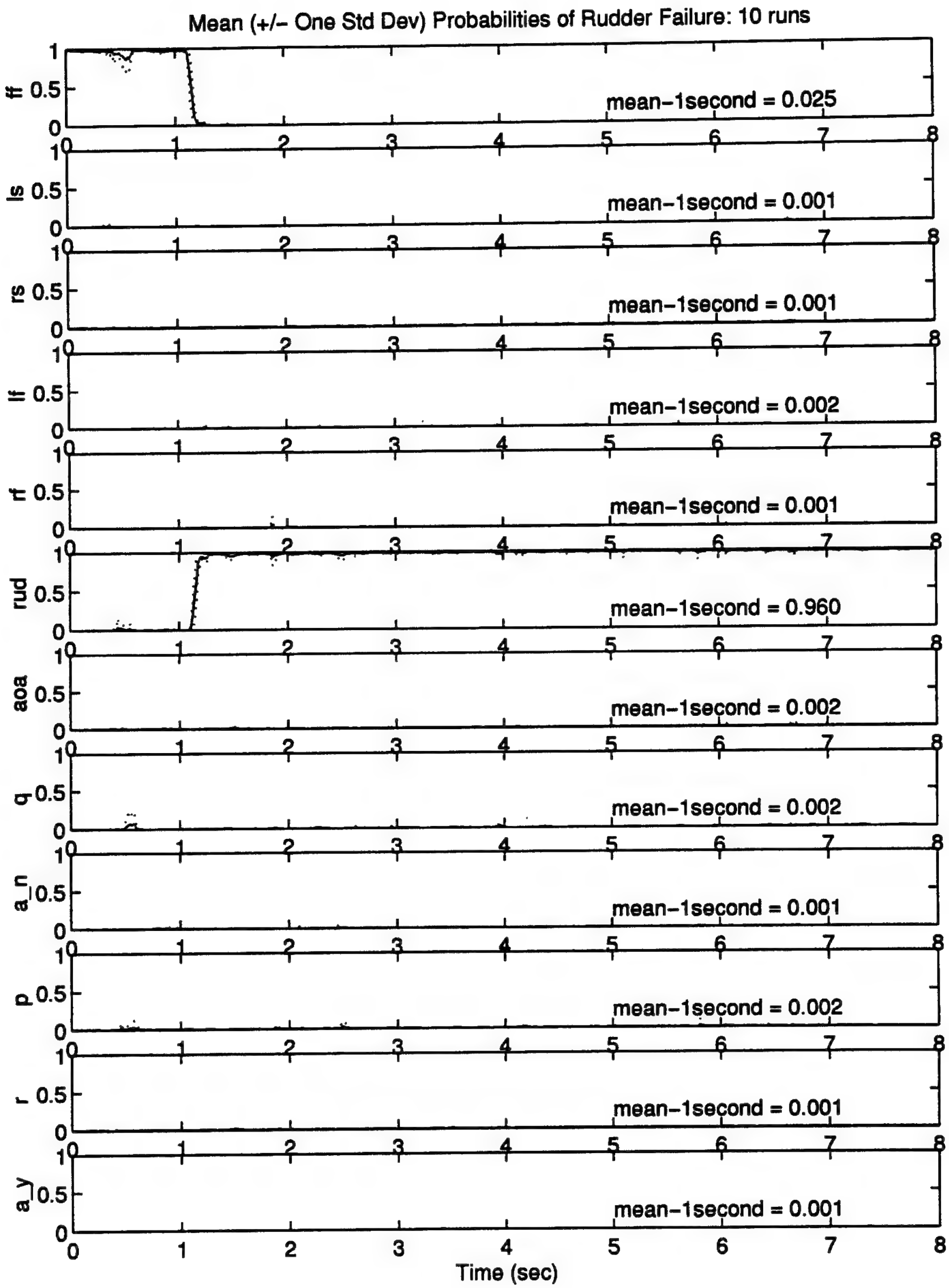
Mean (+/- One Std Dev) Probabilities of Left Stabilator Failure: 10 runs
ff
mean-1second = 0.017
ls
mean-1second = 0.962
rs
mean-1second = 0.002
lf
mean-1second = 0.001
rf
mean-1second = 0.002
rud
mean-1second = 0.003
aoa
mean-1second = 0.003
q
mean-1second = 0.003
a_n
mean-1second = 0.002
p
mean-1second = 0.002
r
mean-1second = 0.002
a_y
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Right Stabilator Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
mean-1second = 0.008
mean-1second = 0.001
mean-1second = 0.970
mean-1second = 0.004
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.003
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Left Flaperon Failure: 10 runs
ff
mean-1second = 0.030
ls
mean-1second = 0.002
rs
mean-1second = 0.002
lf
mean-1second = 0.936
rf
mean-1second = 0.013
rud
mean-1second = 0.002
aoa
mean-1second = 0.002
q
mean-1second = 0.002
a_n
mean-1second = 0.006
p
mean-1second = 0.003
r
mean-1second = 0.002
a_y
mean-1second = 0.001
Time (sec)



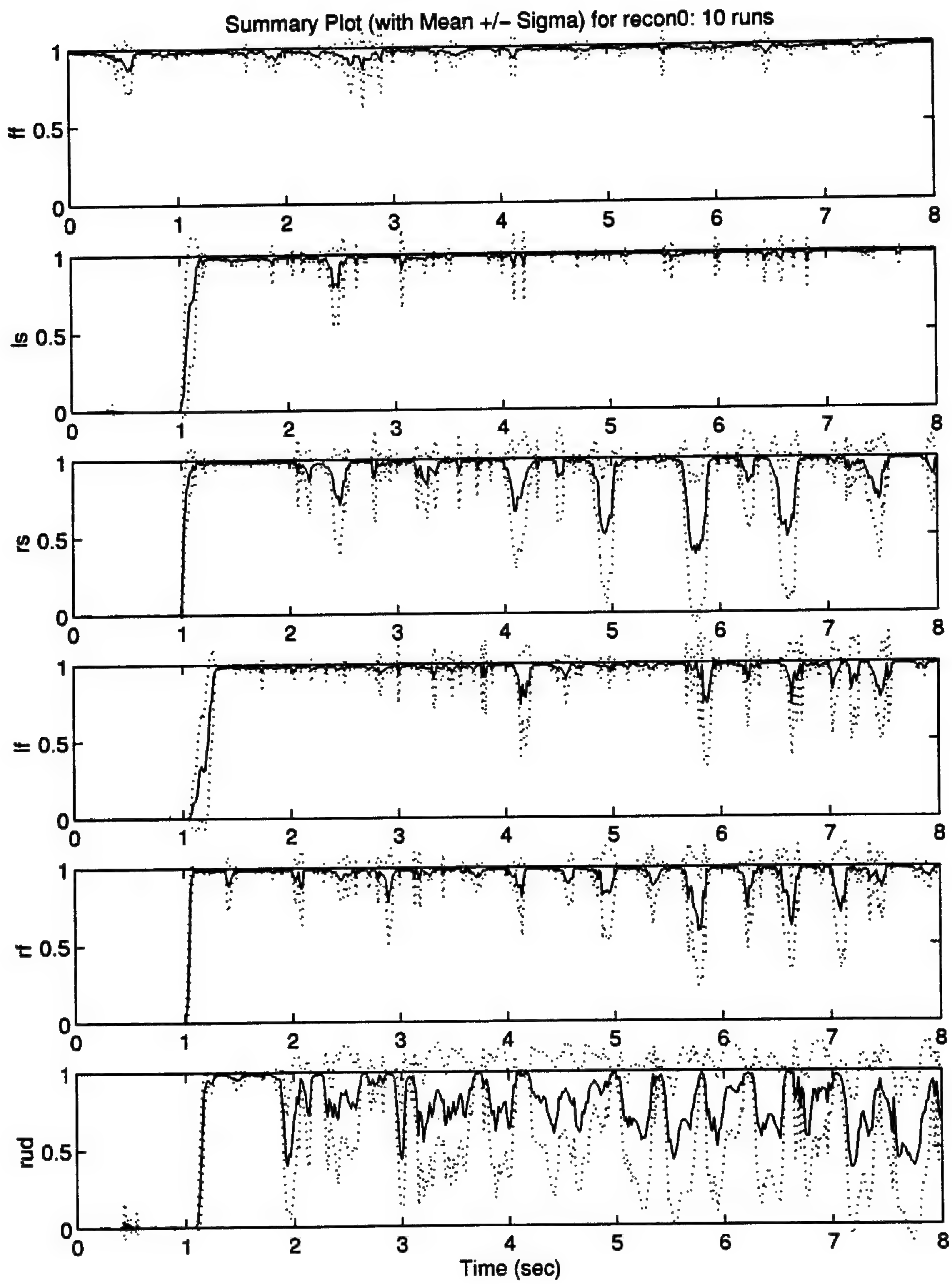
Mean (+/- One Std Dev) Probabilities of Right Flaperon Failure: 10 runs
ff
mean-1second = 0.014
ls
mean-1second = 0.002
rs
mean-1second = 0.002
lf
mean-1second = 0.011
rf
mean-1second = 0.947
rud
mean-1second = 0.002
aoa
mean-1second = 0.003
q
mean-1second = 0.007
a_n
mean-1second = 0.003
p
mean-1second = 0.005
r
mean-1second = 0.003
a_y
mean-1second = 0.001
Time (sec)



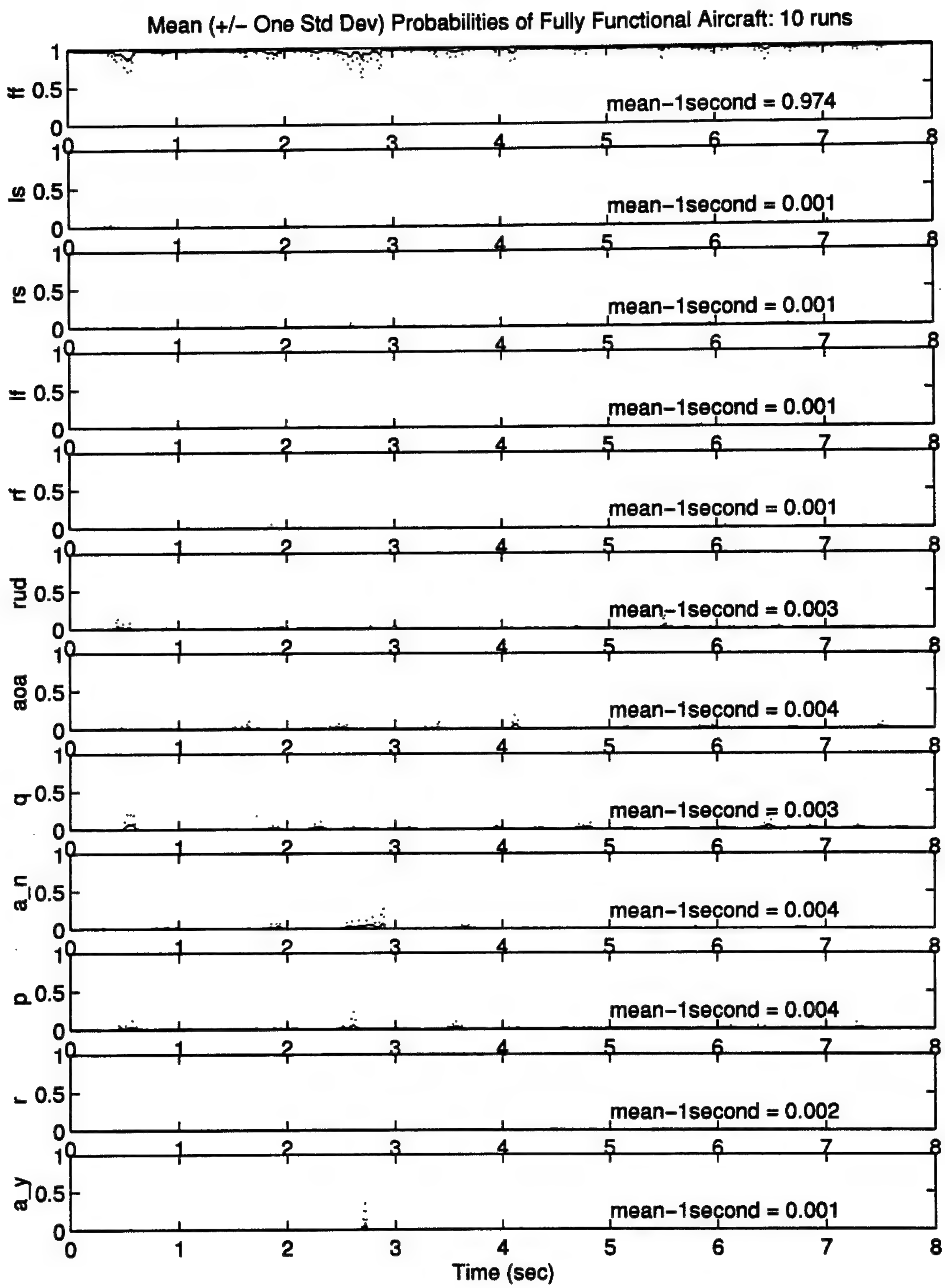
Mean (+/- One Std Dev) Probabilities of Rudder Failure: 10 runs
ff
mean-1second = 0.025
ls
mean-1second = 0.001
rs
mean-1second = 0.001
lf
mean-1second = 0.002
rf
mean-1second = 0.001
rud
mean-1second = 0.960
aoa
mean-1second = 0.002
q
mean-1second = 0.002
a_n
mean-1second = 0.001
p
mean-1second = 0.002
r
mean-1second = 0.001
a_y
mean-1second = 0.001
Time (sec)

Appendix A.2: Single Total Actuator Impairments ($\varepsilon = 0$), Control Redistribution 'ON', Dither 'ON', No Maneuvers

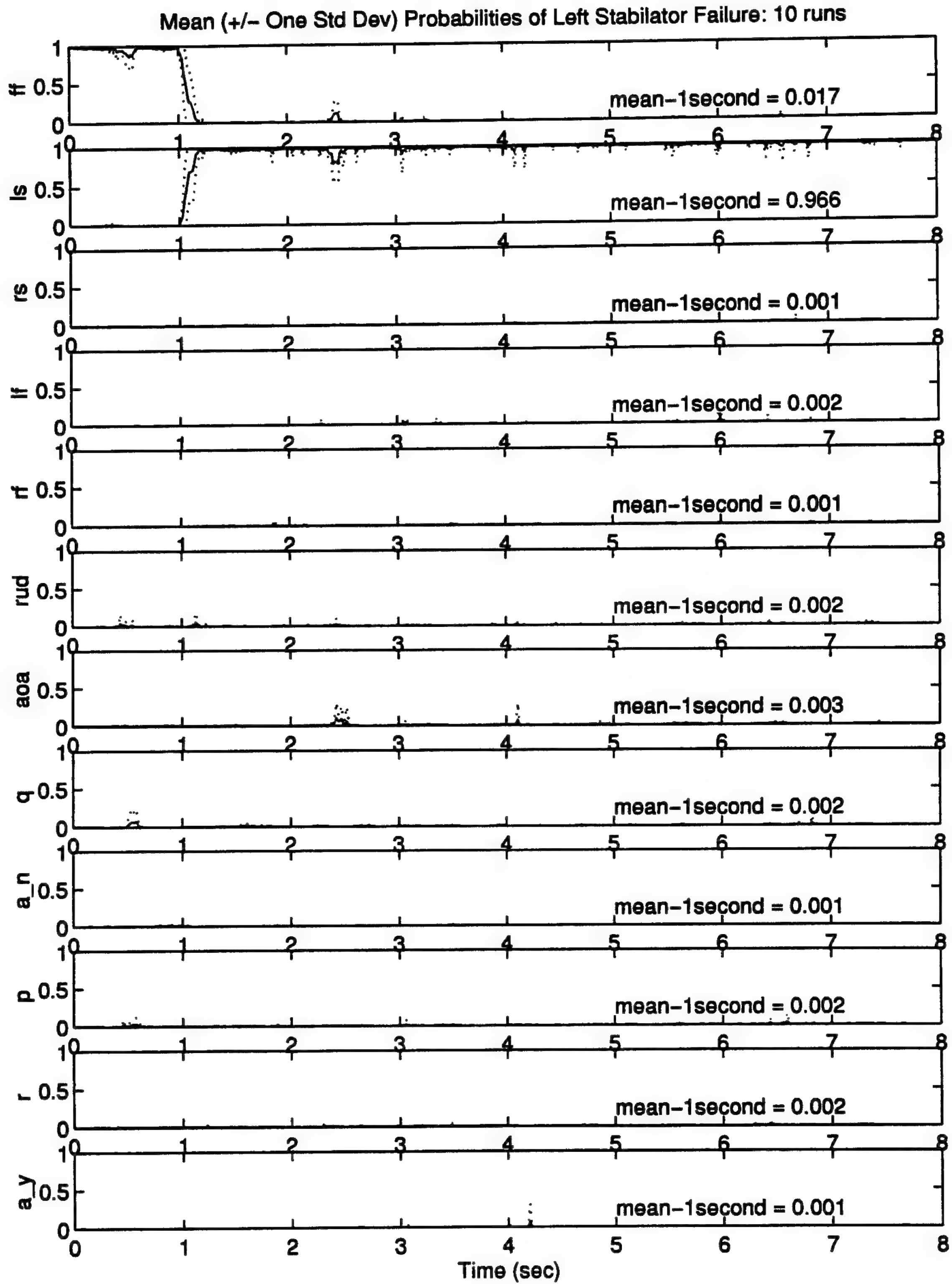
This appendix contains the Probability Summary Plot and individual probability plots for cases of single, total (100%) actuator impairments, without aircraft maneuvering, but *with* Control Reconfiguration (Redistribution), and with control dithering (Section 4.11.2).



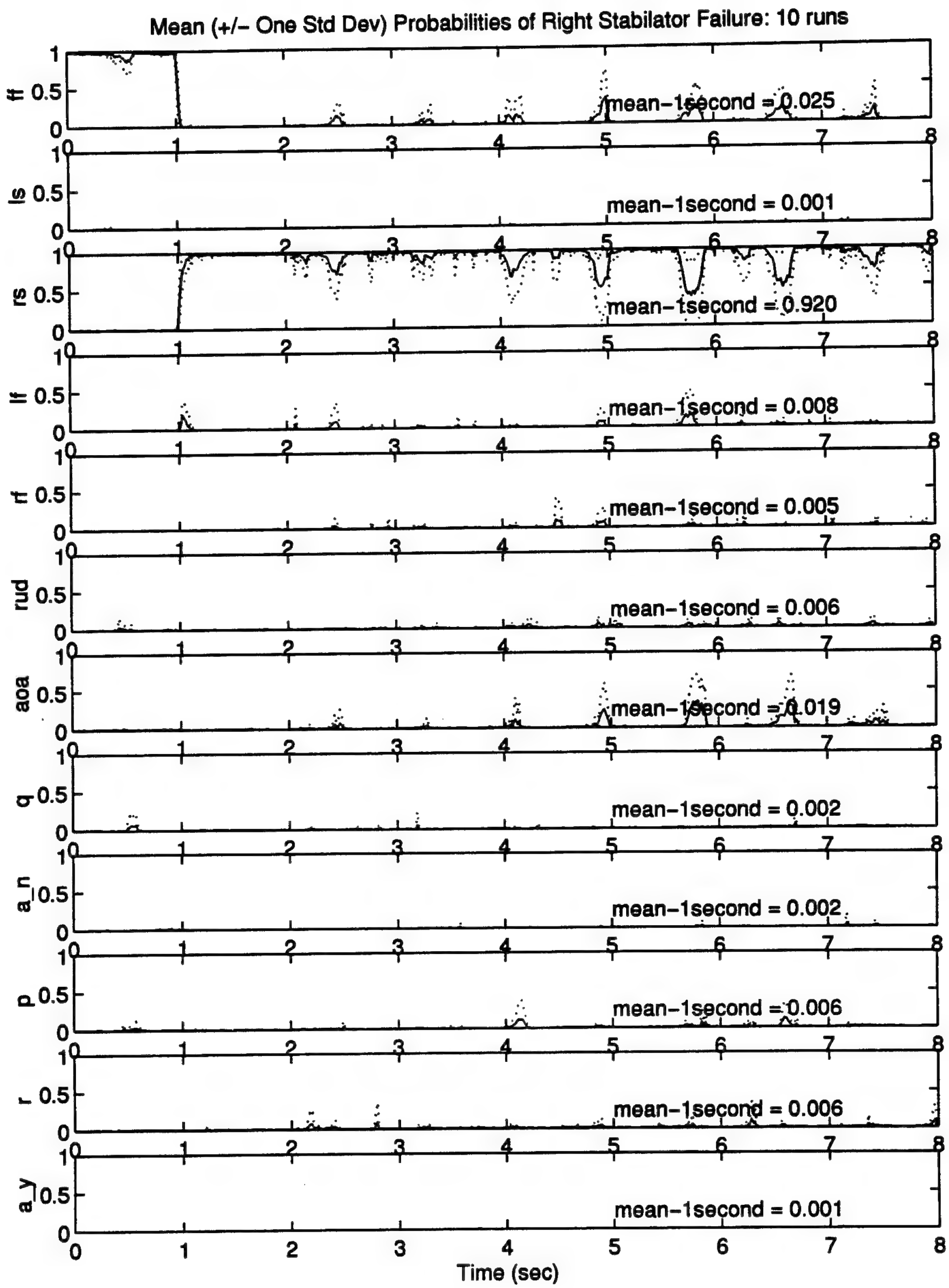
Summary Plot (with Mean +/- Sigma) for recon0: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)

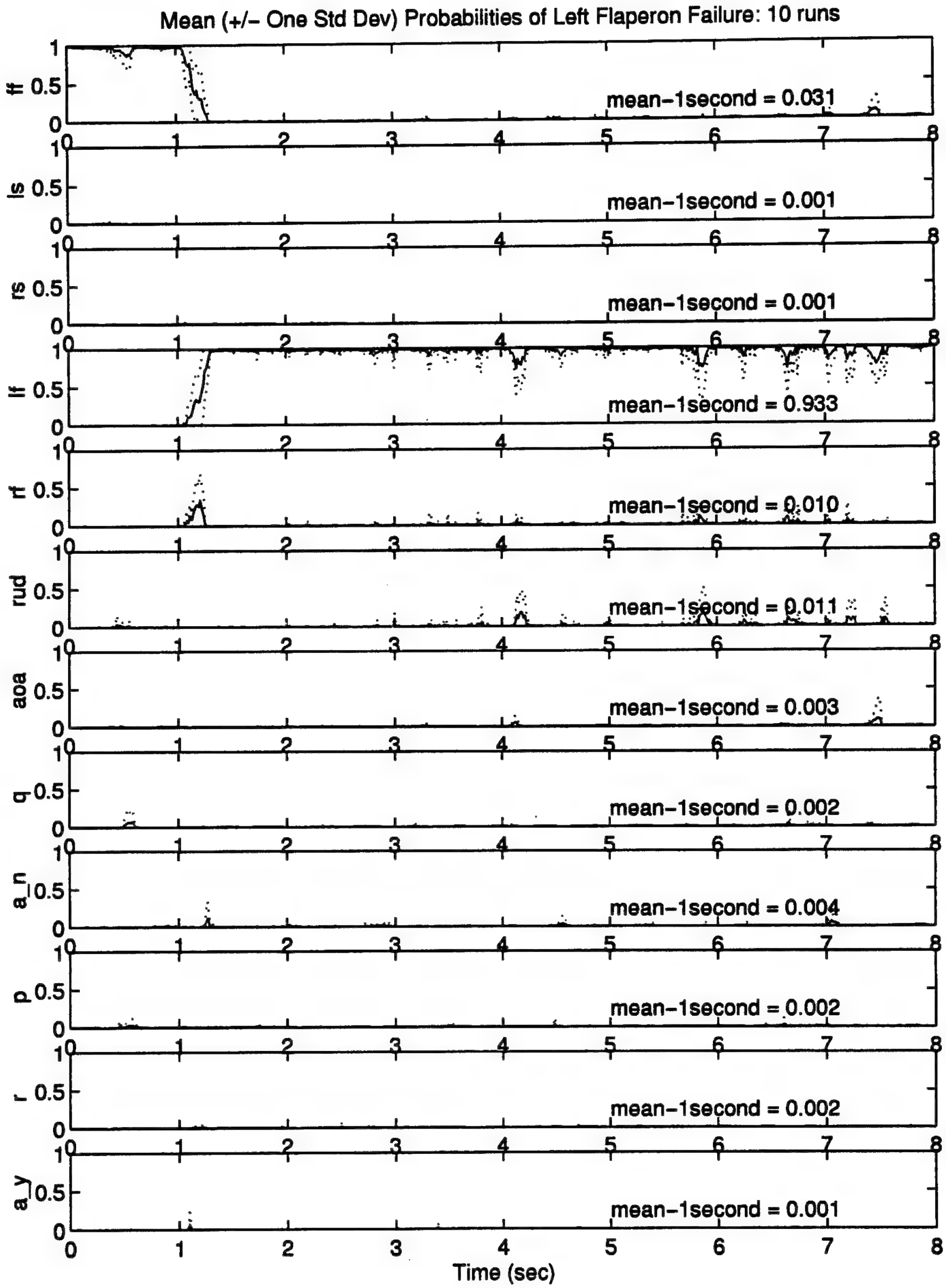


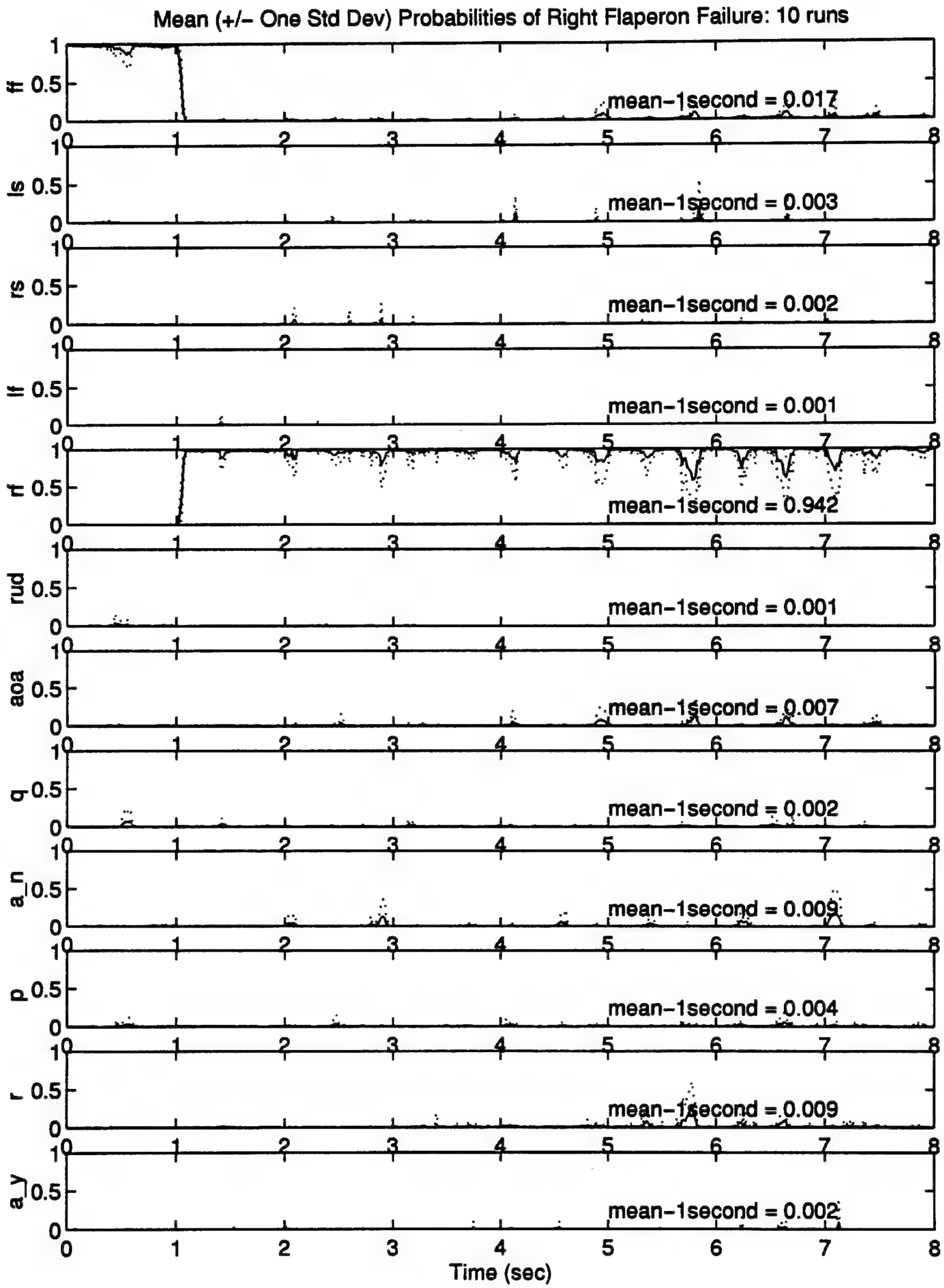
Mean (+/- One Std Dev) Probabilities of Fully Functional Aircraft: 10 runs
ff
mean-1second = 0.974
ls
mean-1second = 0.001
rs
mean-1second = 0.001
lf
mean-1second = 0.001
rf
mean-1second = 0.001
rud
mean-1second = 0.003
aoa
mean-1second = 0.004
q
mean-1second = 0.003
a_n
mean-1second = 0.004
p
mean-1second = 0.004
r
mean-1second = 0.002
a_y
mean-1second = 0.001
Time (sec)



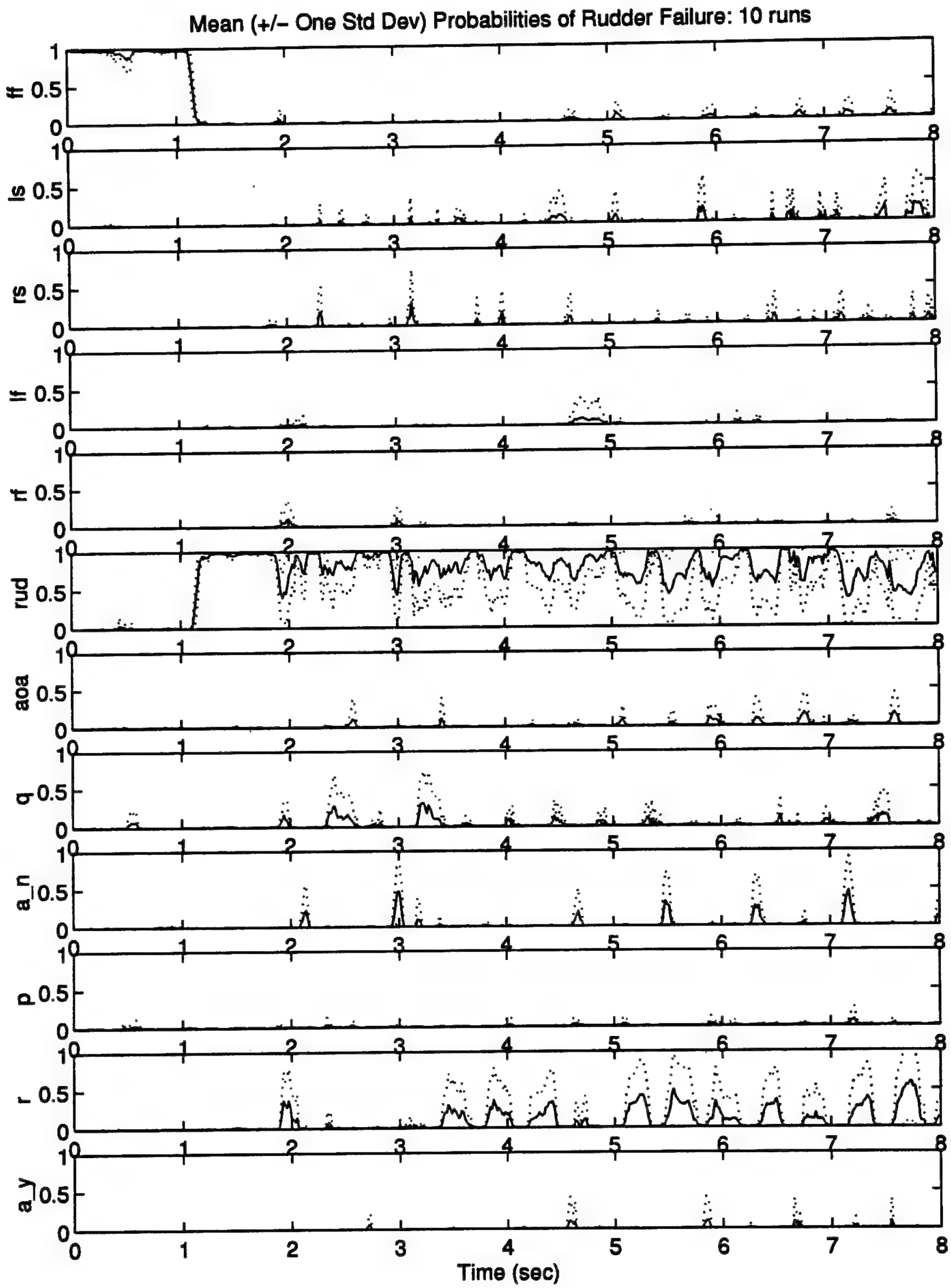
Mean (+/- One Std Dev) Probabilities of Left Stabilator Failure: 10 runs
ff
mean-1second = 0.017
ls
mean-1second = 0.966
rs
mean-1second = 0.001
lf
mean-1second = 0.002
rf
mean-1second = 0.001
rud
mean-1second = 0.002
aoa
mean-1second = 0.003
q
mean-1second = 0.002
a_n
mean-1second = 0.001
p
mean-1second = 0.002
r
mean-1second = 0.002
a_y
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Right Stabilator Failure: 10 runs
ff
mean-1second = 0.025
ls
mean-1second = 0.001
rs
mean-1second = 0.920
lf
mean-1second = 0.008
rf
mean-1second = 0.005
rud
mean-1second = 0.006
aoa
mean-1second = 0.019
q
mean-1second = 0.002
a_n
mean-1second = 0.002
p
mean-1second = 0.006
r
mean-1second = 0.006
a_y
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Left Flaperon Failure: 10 runs
ff
mean-1second = 0.031
ls
mean-1second = 0.001
rs
mean-1second = 0.001
lf
mean-1second = 0.933
rf
mean-1second = 0.010
rud
mean-1second = 0.011
aoa
mean-1second = 0.003
q
mean-1second = 0.002
a_n
mean-1second = 0.004
p
mean-1second = 0.002
r
mean-1second = 0.002
a_y
mean-1second = 0.001
Time (sec)

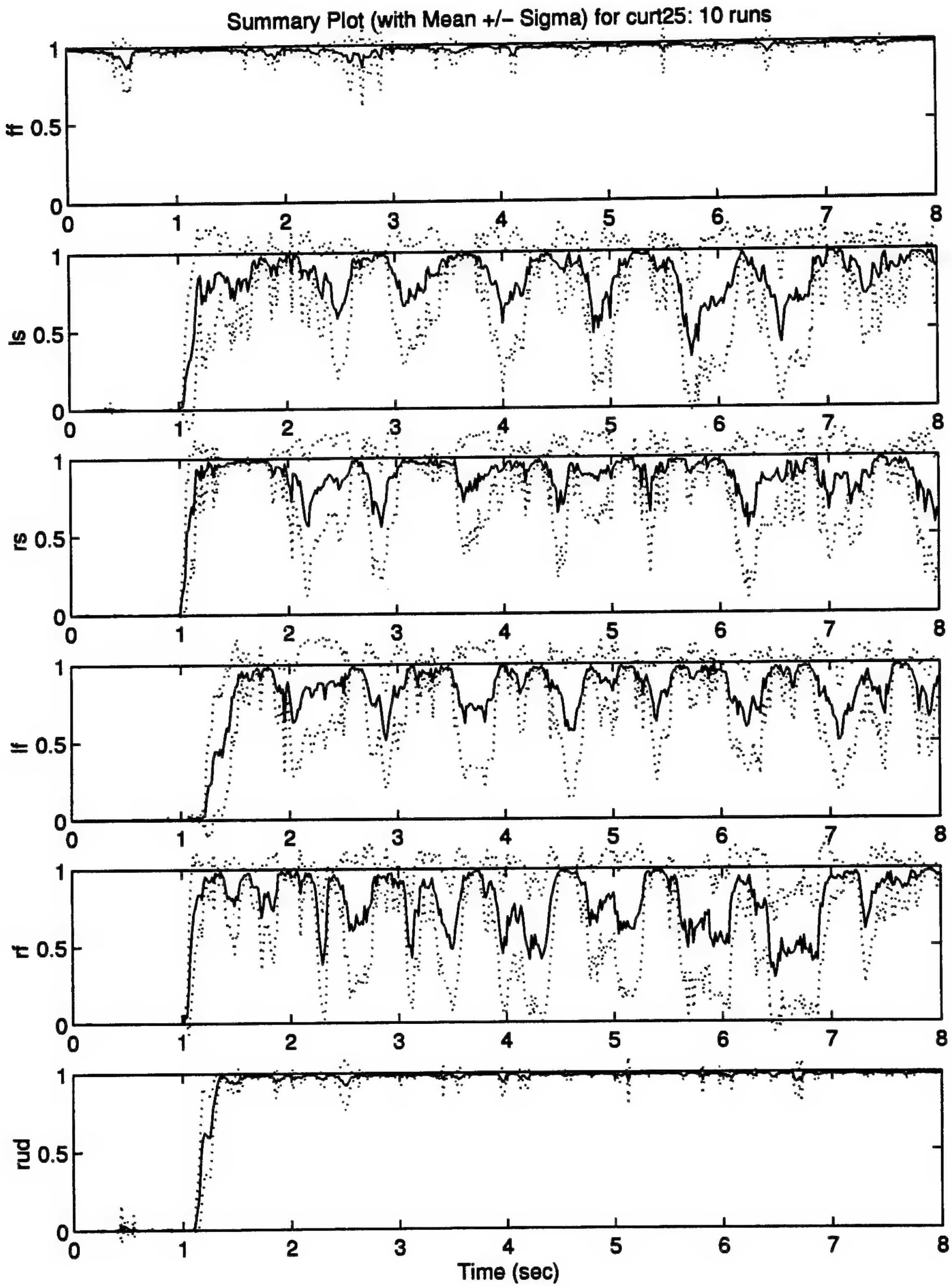


Mean (+/- One Std Dev) Probabilities of Right Flaperon Failure: 10 runs
ff
mean-1second = 0.017
ls
mean-1second = 0.003
rs
mean-1second = 0.002
lf
mean-1second = 0.001
rf
mean-1second = 0.942
rud
mean-1second = 0.001
aoa
mean-1second = 0.007
q
mean-1second = 0.002
a_n
mean-1second = 0.009
p
mean-1second = 0.004
r
mean-1second = 0.009
a_y
mean-1second = 0.002
Time (sec)

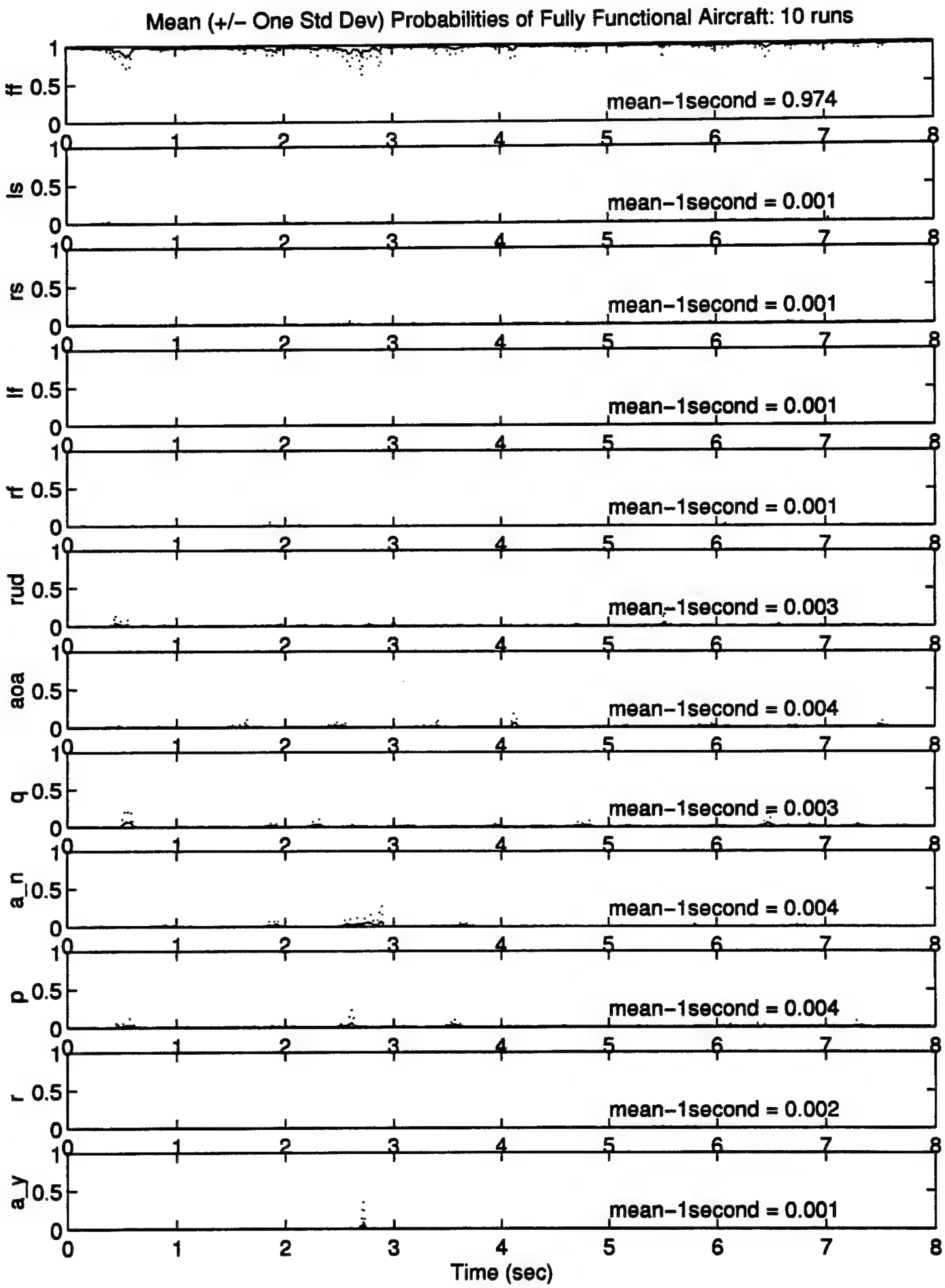

Mean (+/- One Std Dev) Probabilities of Rudder Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec)

Appendix B.1: Single 75% Actuator Impairments ($\varepsilon = .25$), Control Redistribution 'OFF', Dither 'ON', No Maneuvers

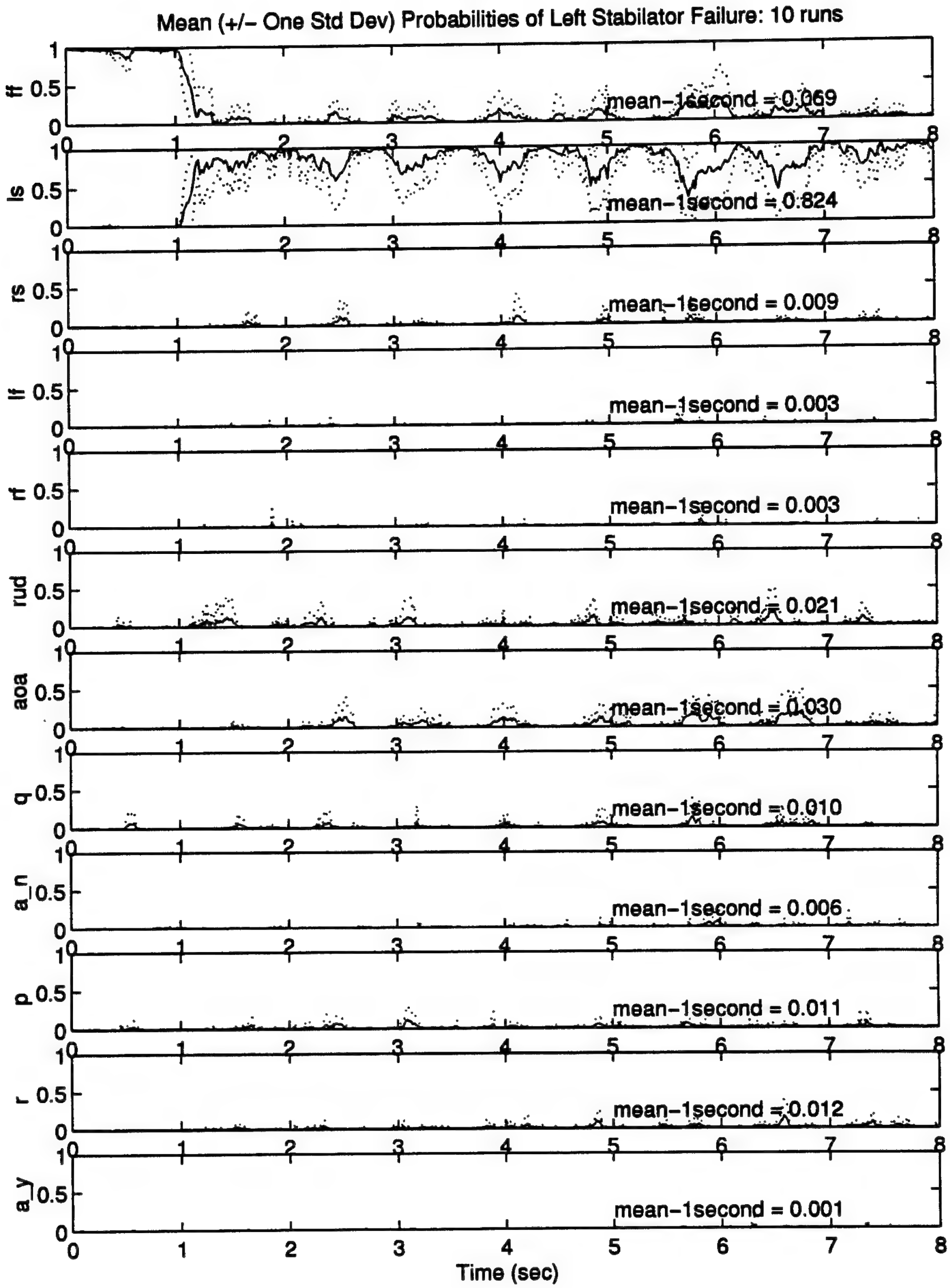
This appendix contains the Probability Summary Plot and individual probability plots for cases of single, 75% ($\varepsilon = .25$) actuator impairments, without aircraft maneuvering or Control Reconfiguration (Redistribution), but with control dithering (Section 4.12.1).



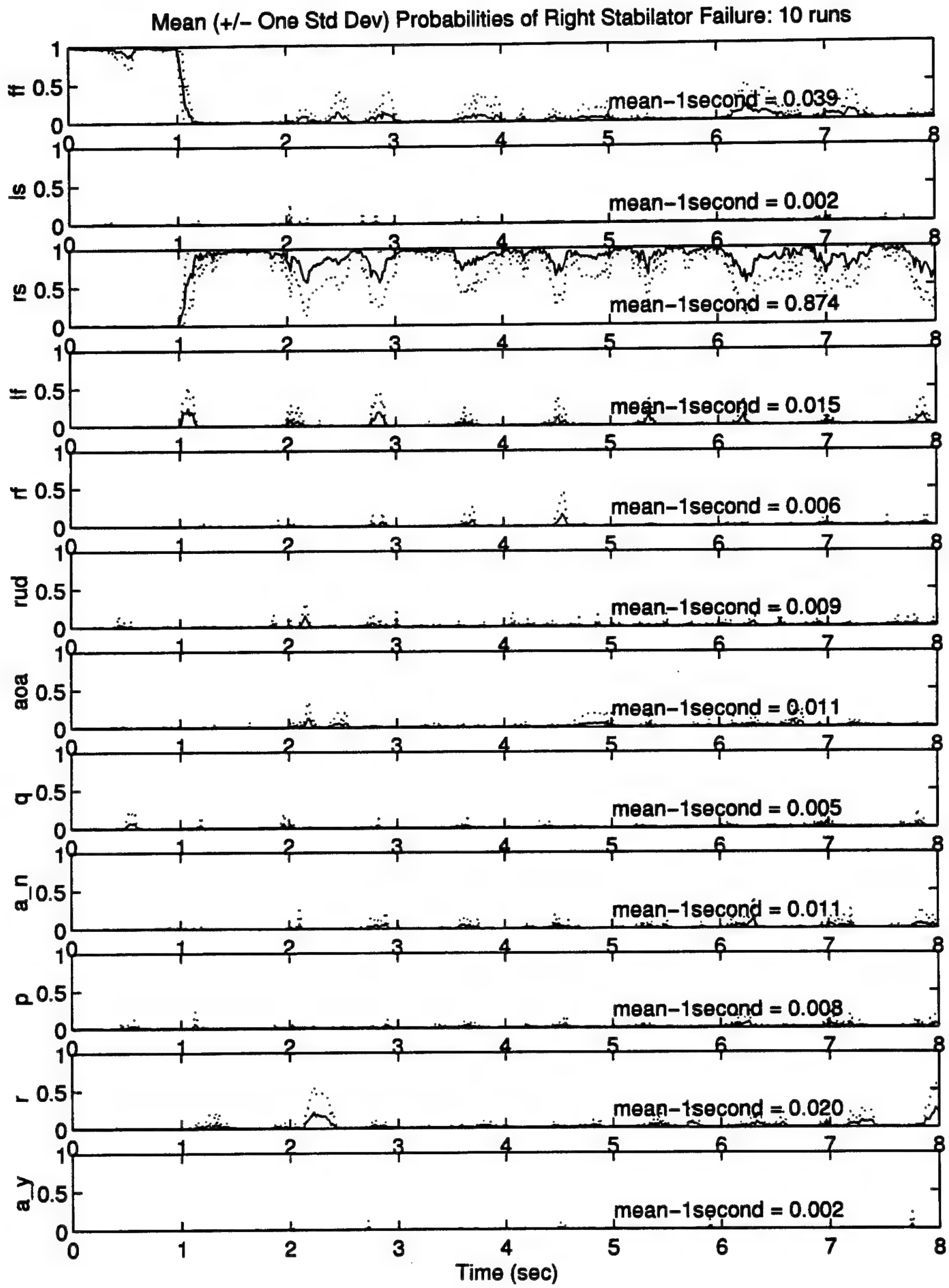
Summary Plot (with Mean +/- Sigma) for curt25: 10 runs
ff
ls
rs
lf
rf
rud
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec)



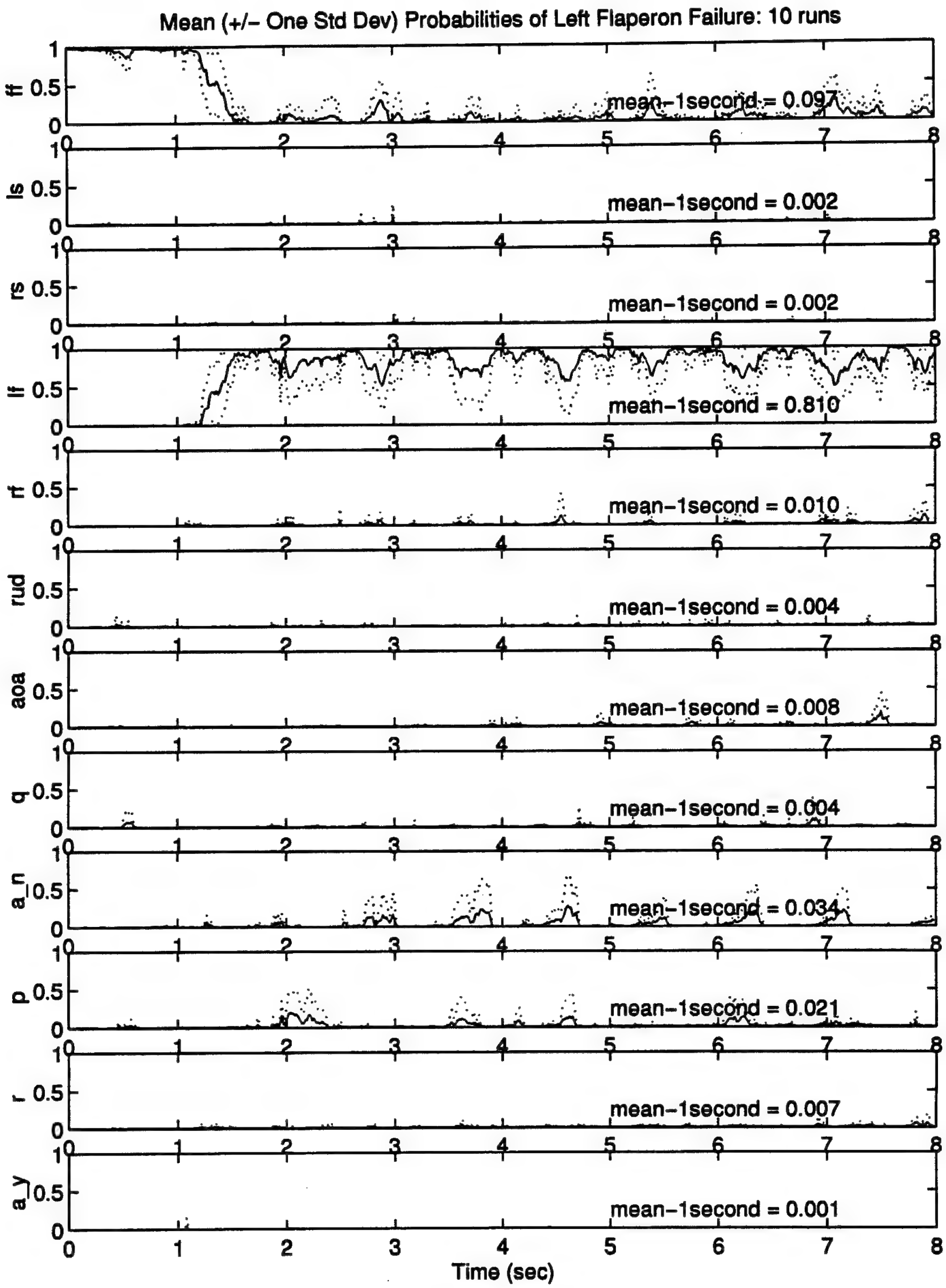
Mean (+/- One Std Dev) Probabilities of Fully Functional Aircraft: 10 runs
ff
mean-1second = 0.974
ls
mean-1second = 0.001
rs
mean-1second = 0.001
lf
mean-1second = 0.001
rf
mean-1second = 0.001
rud
mean-1second = 0.003
aoa
mean-1second = 0.004
q
mean-1second = 0.003
a_n
mean-1second = 0.004
p
mean-1second = 0.004
r
mean-1second = 0.002
a_y
mean-1second = 0.001
Time (sec)



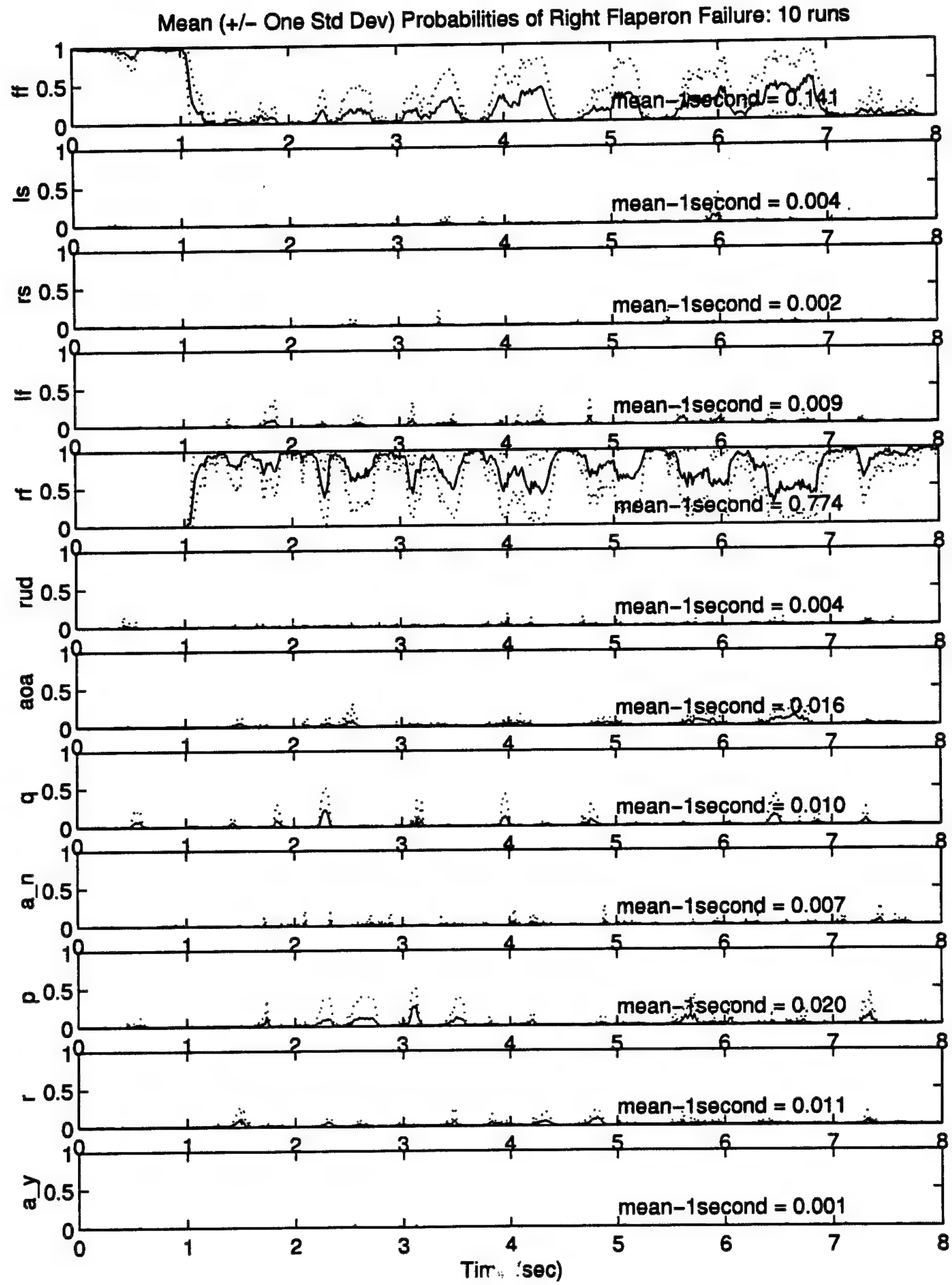
Mean (+/- One Std Dev) Probabilities of Left Stabilator Failure: 10 runs
ff
mean-1second = 0.069
ls
mean-1second = 0.824
rs
mean-1second = 0.009
lf
mean-1second = 0.003
rf
mean-1second = 0.003
rud
mean-1second = 0.021
aoa
mean-1second = 0.030
q
mean-1second = 0.010
a_n
mean-1second = 0.006
p
mean-1second = 0.011
r
mean-1second = 0.012
a_y
mean-1second = 0.001
Time (sec)



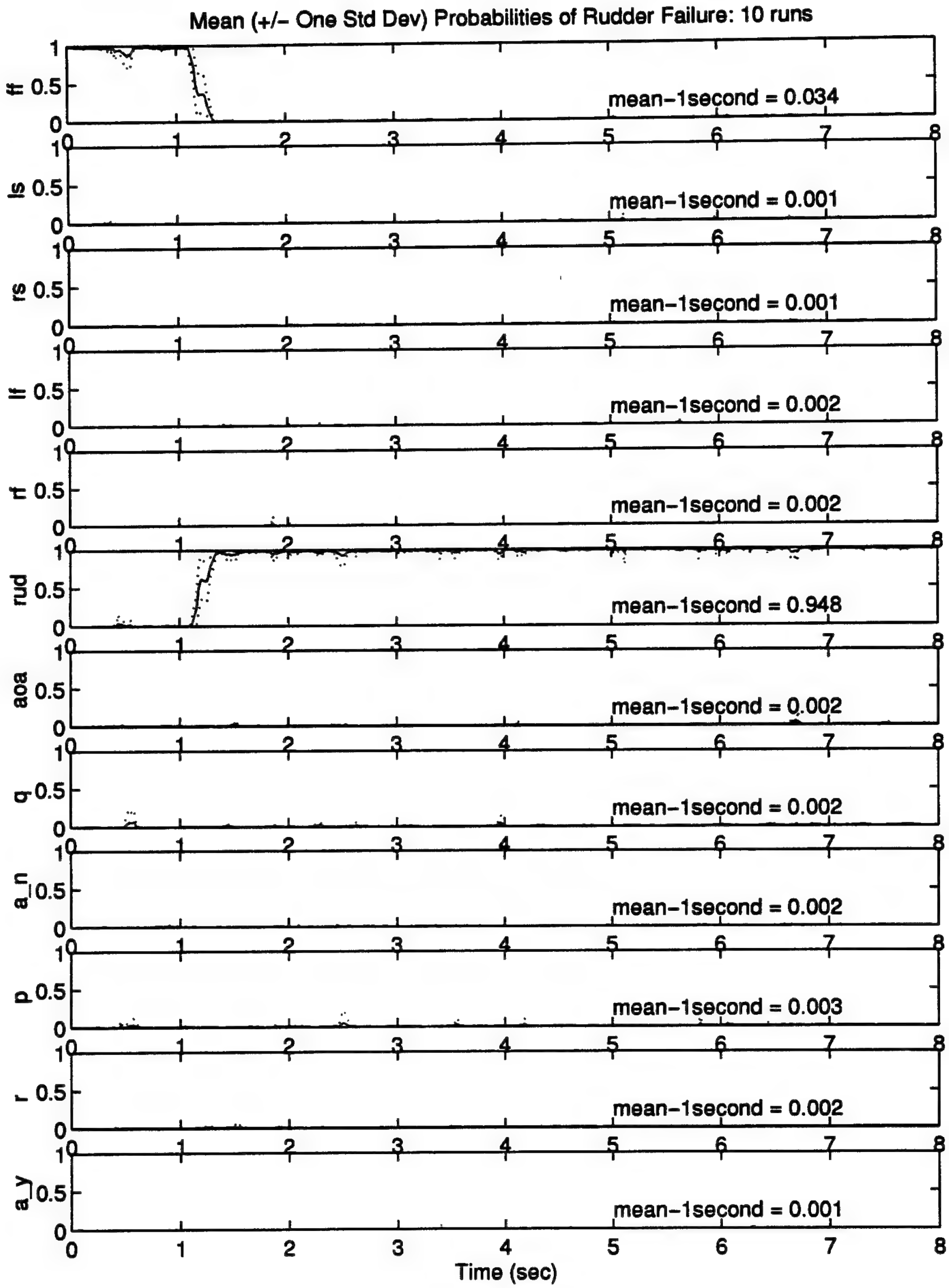
Mean (+/- One Std Dev) Probabilities of Right Stabilator Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
mean-1second = 0.039
mean-1second = 0.002
mean-1second = 0.874
mean-1second = 0.015
mean-1second = 0.006
mean-1second = 0.009
mean-1second = 0.011
mean-1second = 0.005
mean-1second = 0.011
mean-1second = 0.008
mean-1second = 0.020
mean-1second = 0.002
0 0.5 1
0 1 2 3 4 5 6 7 8
Time (sec)



Mean (+/- One Std Dev) Probabilities of Left Flaperon Failure: 10 runs
ff
mean-1second = 0.097
ls
mean-1second = 0.002
rs
mean-1second = 0.002
lf
mean-1second = 0.810
rf
mean-1second = 0.010
rud
mean-1second = 0.004
aoa
mean-1second = 0.008
q
mean-1second = 0.004
a_n
mean-1second = 0.034
p
mean-1second = 0.021
r
mean-1second = 0.007
a_y
mean-1second = 0.001
Time (sec)

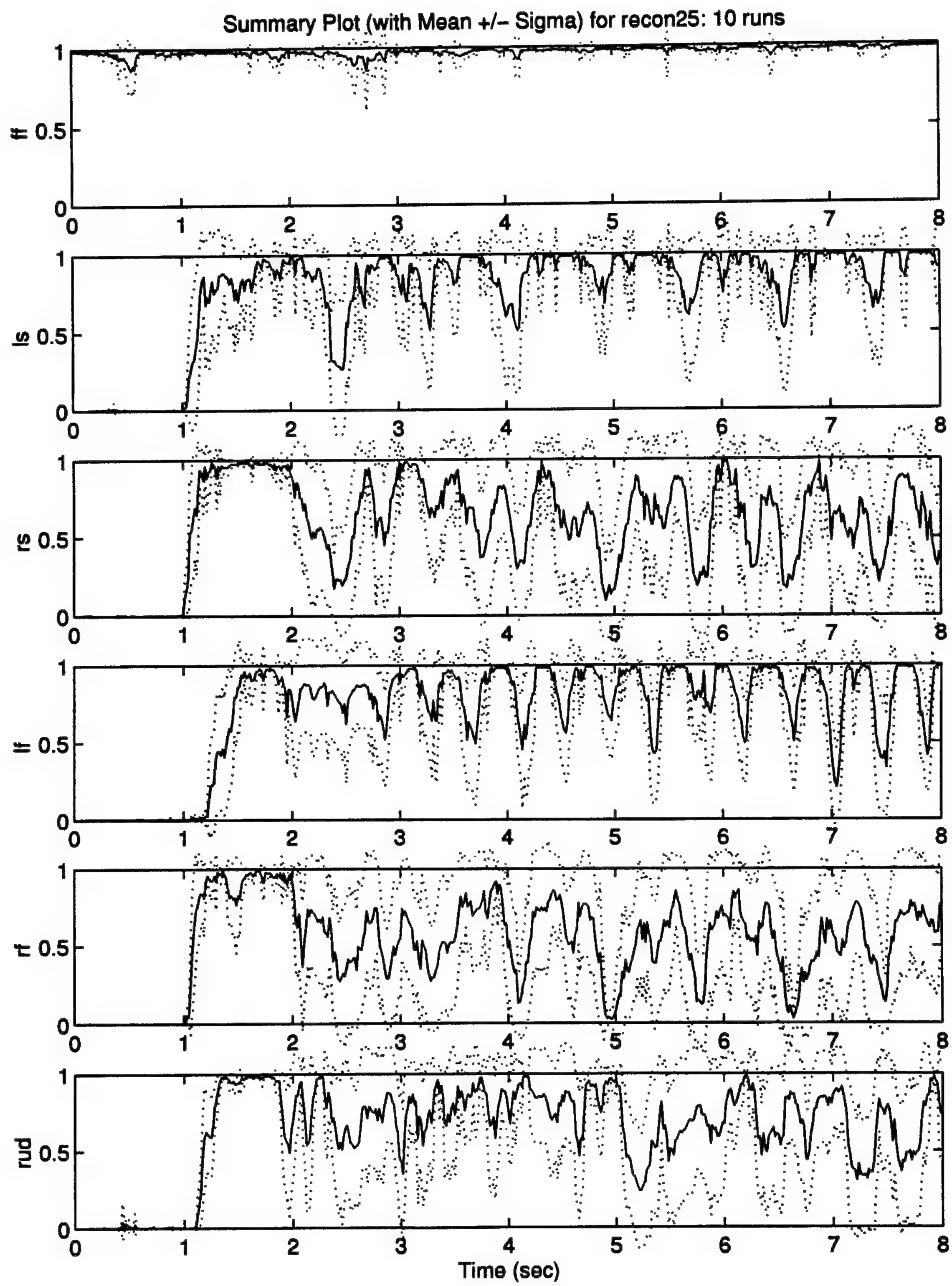


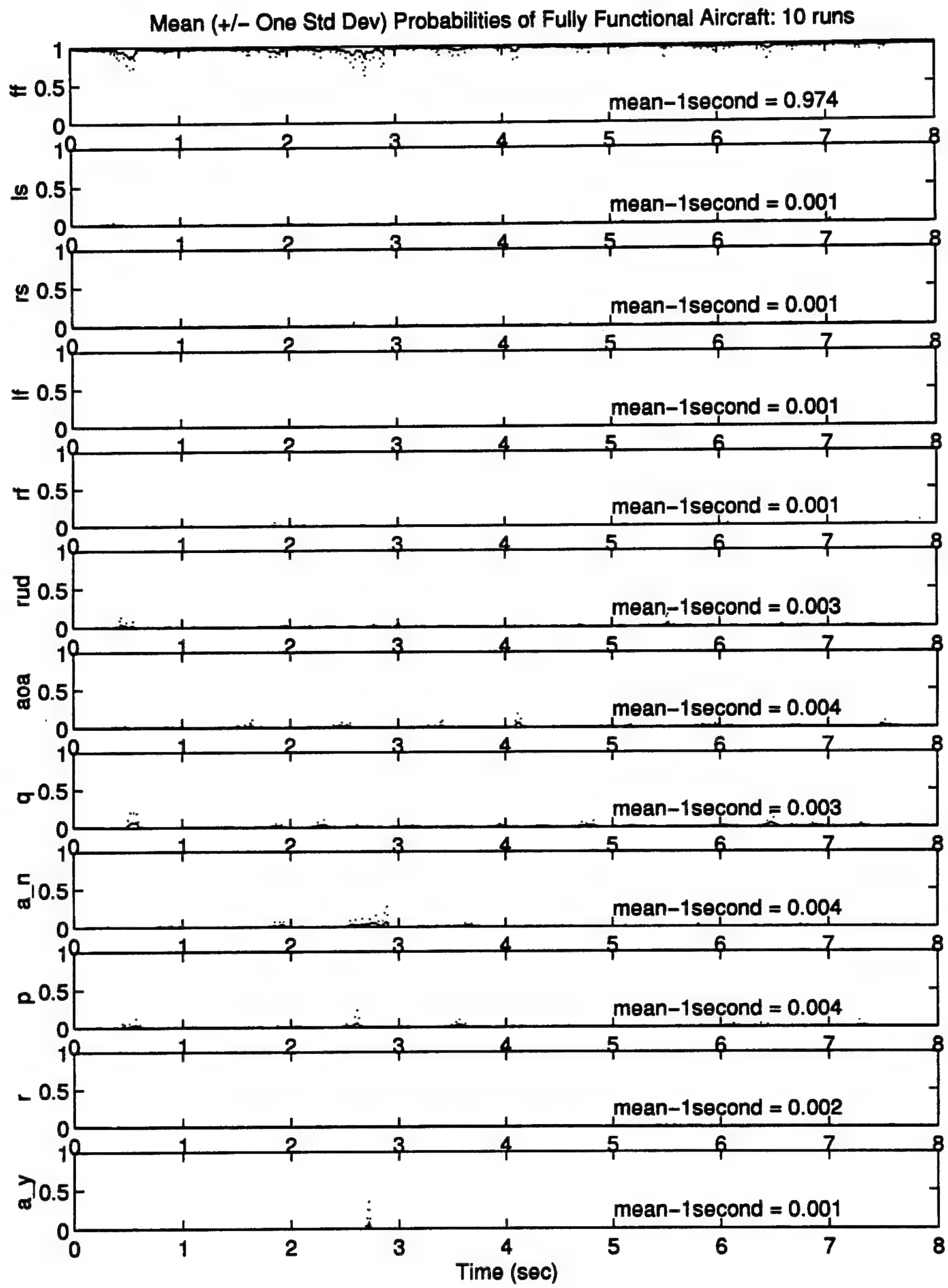
Mean (+/- One Std Dev) Probabilities of Right Flaperon Failure: 10 runs
ff
mean-1second = 0.141
ls
mean-1second = 0.004
rs
mean-1second = 0.002
lf
mean-1second = 0.009
rf
mean-1second = 0.774
rud
mean-1second = 0.004
aoa
mean-1second = 0.016
q
mean-1second = 0.010
a_n
mean-1second = 0.007
p
mean-1second = 0.020
r
mean-1second = 0.011
a_y
mean-1second = 0.001
Time (sec)

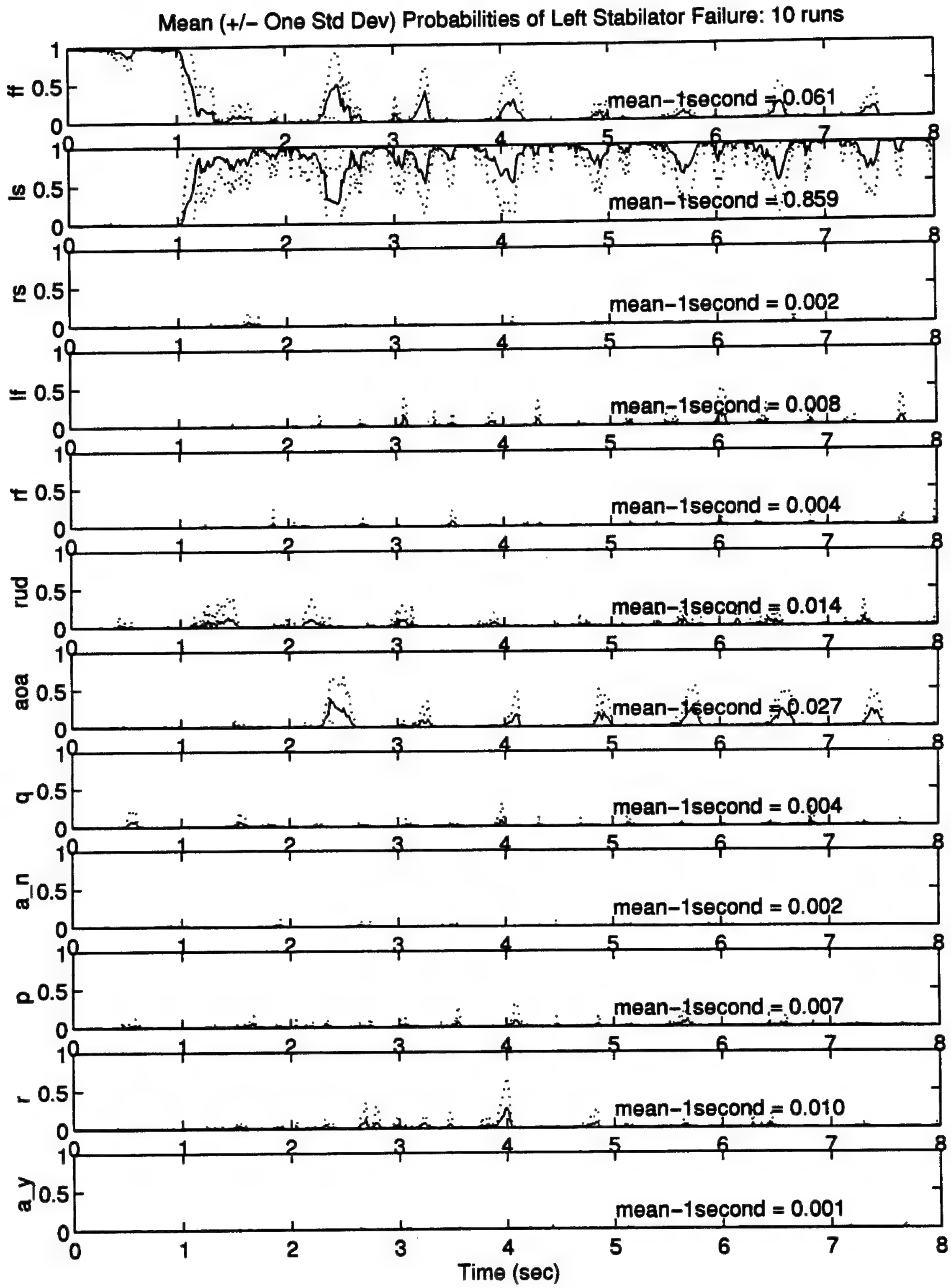

Mean (+/- One Std Dev) Probabilities of Rudder Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
mean-1second = 0.034
mean-1second = 0.001
mean-1second = 0.001
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.948
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.002
mean-1second = 0.003
mean-1second = 0.002
mean-1second = 0.001
Time (sec)

Appendix B.2: Single 75% Actuator Impairments ($\varepsilon = .25$), Control Redistribution 'ON', Dither 'ON', No Maneuvers

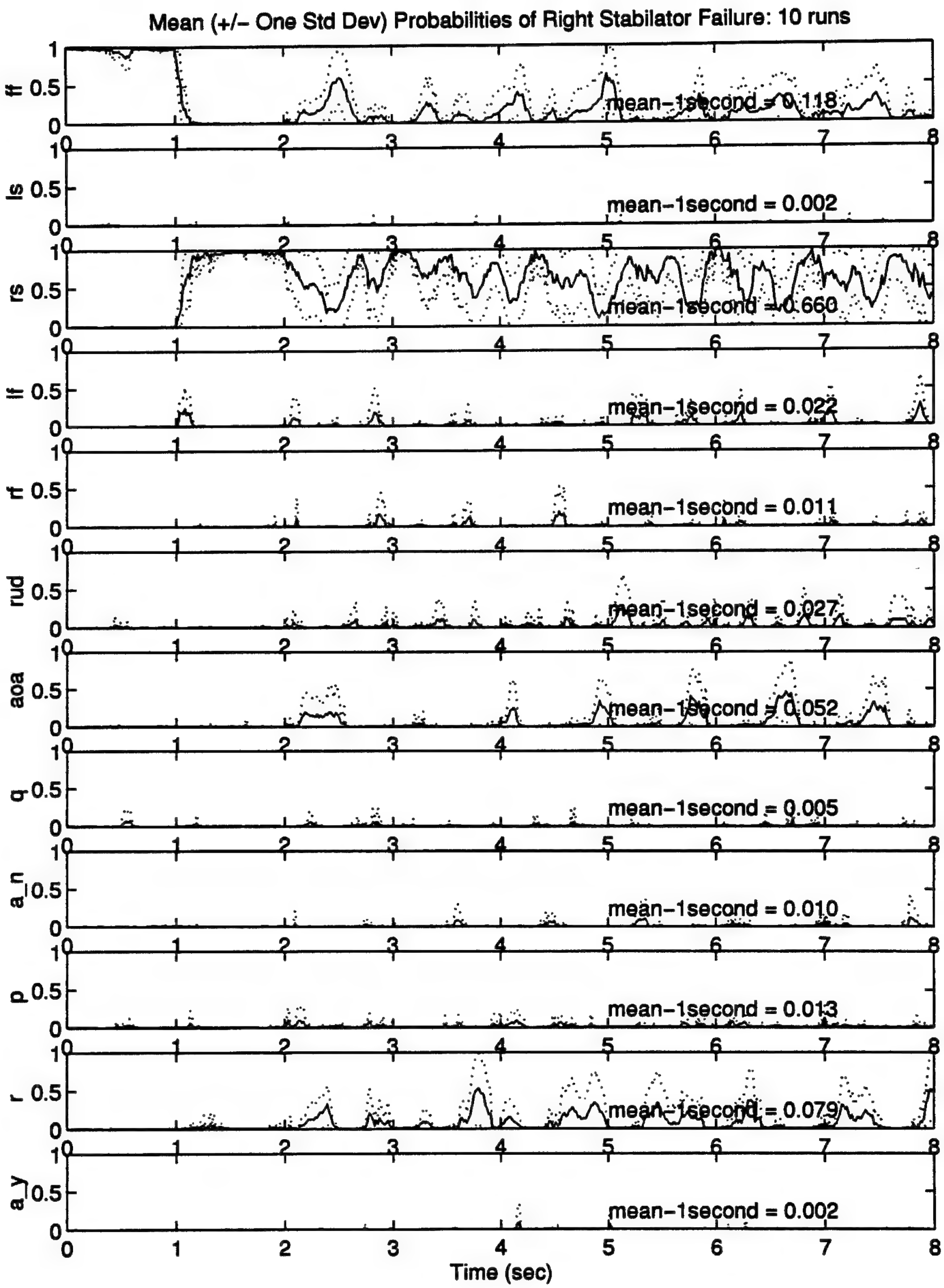
This appendix contains the Probability Summary Plot and individual probability plots for cases of single, 75% ($\varepsilon = .25$) actuator impairments, without aircraft maneuvering, but with Control Reconfiguration (Redistribution), and with control dithering (Section 4.12.2).

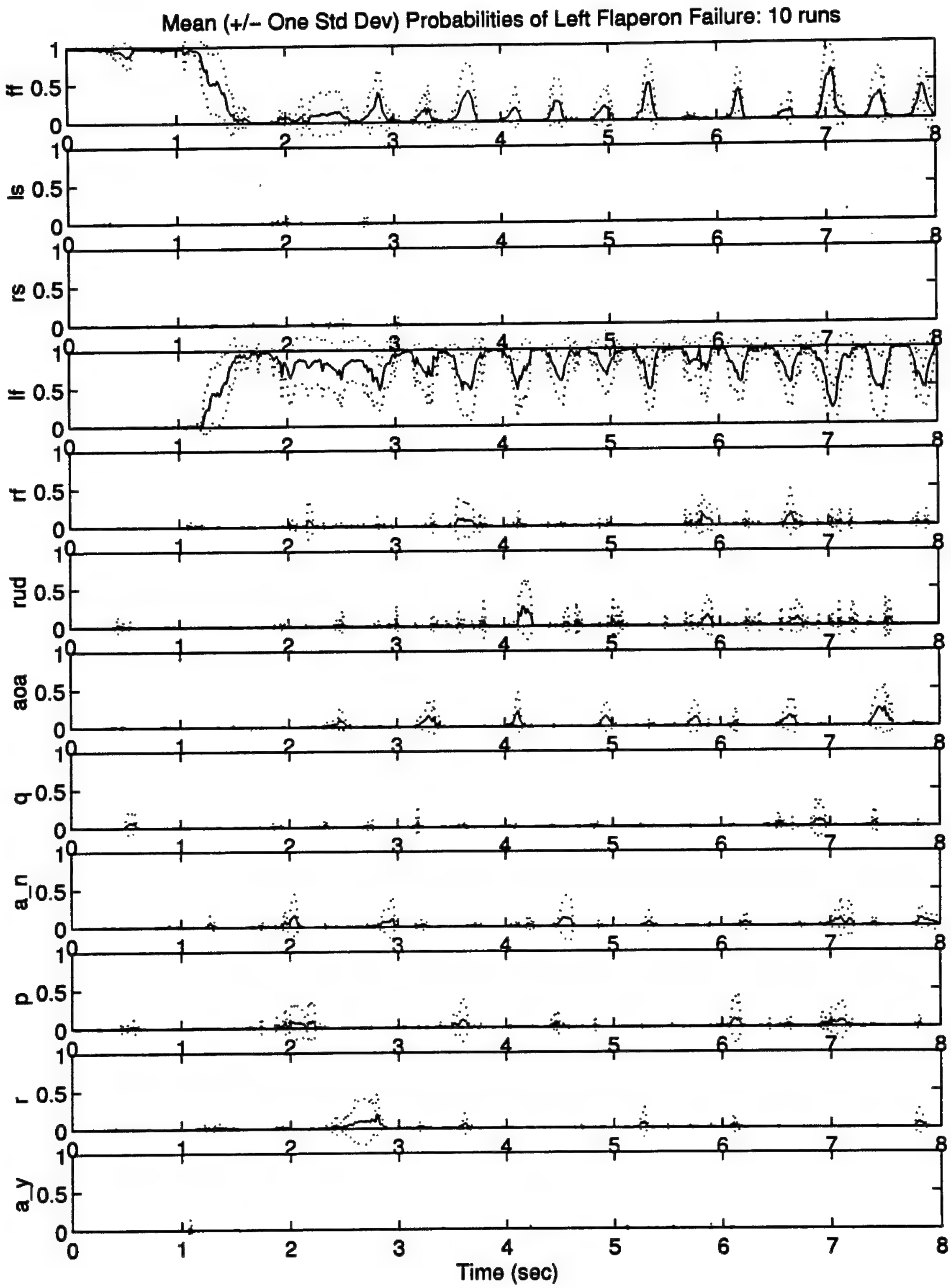

Summary Plot (with Mean +/- Sigma) for recon25: 10 runs
ff
ls
rs
lf
rf
rud
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec)


Mean (+/- One Std Dev) Probabilities of Fully Functional Aircraft: 10 runs
ff
mean-1second = 0.974
ls
mean-1second = 0.001
rs
mean-1second = 0.001
lf
mean-1second = 0.001
rf
mean-1second = 0.001
rud
mean-1second = 0.003
aoa
mean-1second = 0.004
q
mean-1second = 0.003
a_n
mean-1second = 0.004
p
mean-1second = 0.004
r
mean-1second = 0.002
a_y
mean-1second = 0.001
Time (sec)

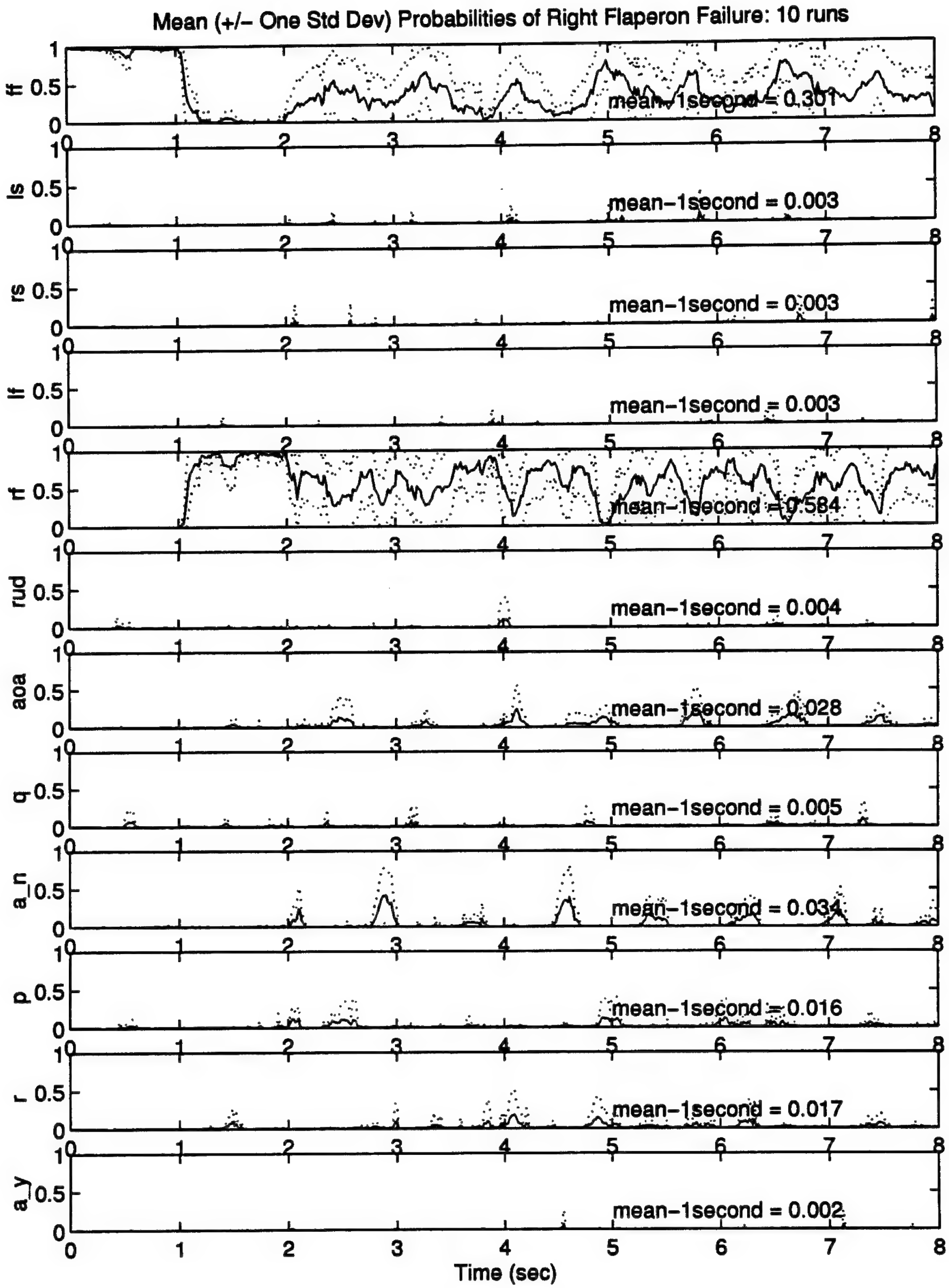


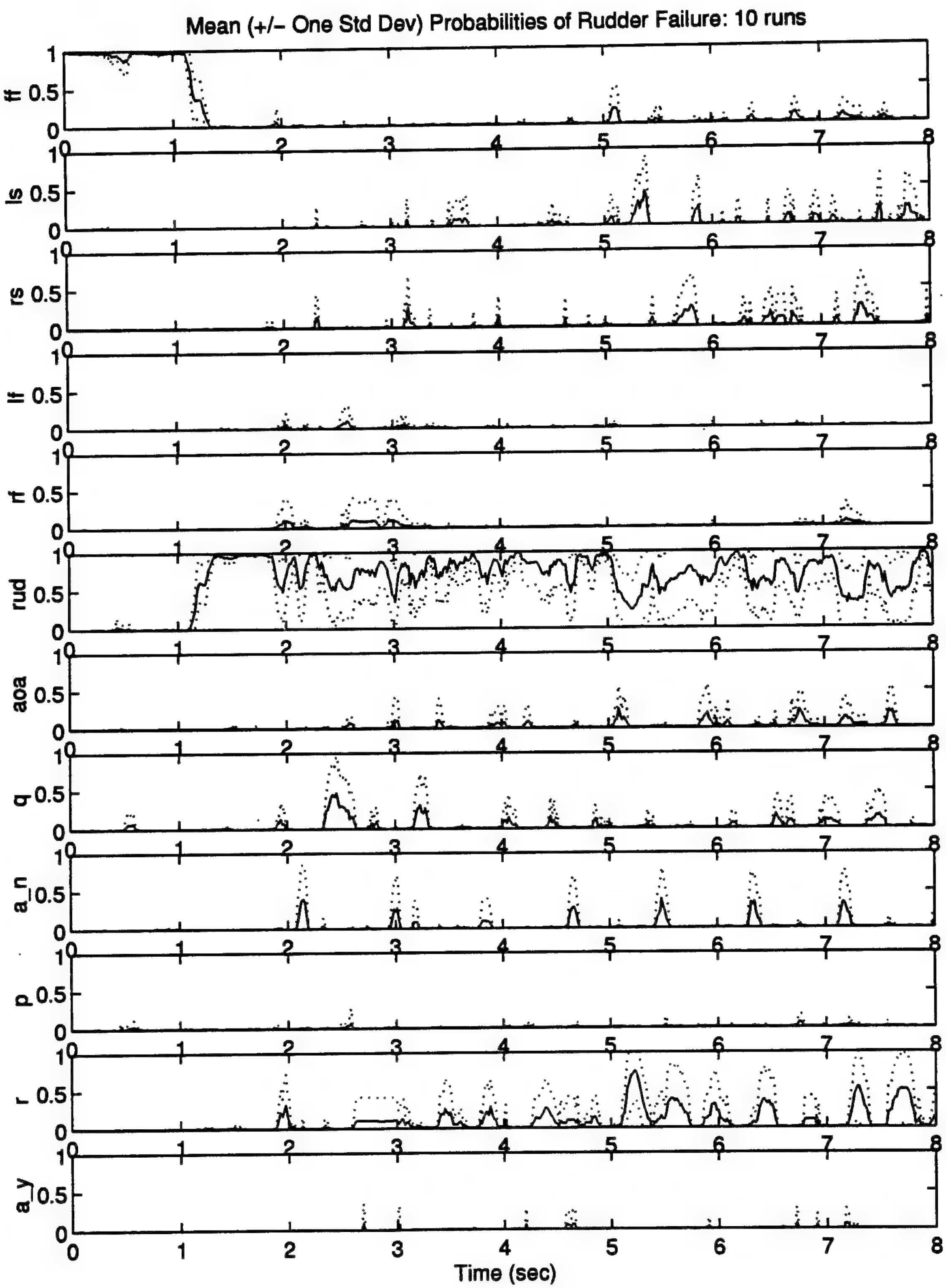
Mean (+/- One Std Dev) Probabilities of Left Stabilator Failure: 10 runs
ff
mean-1second = 0.061
ls
mean-1second = 0.859
rs
mean-1second = 0.002
lf
mean-1second = 0.008
rf
mean-1second = 0.004
rud
mean-1second = 0.014
aoa
mean-1second = 0.027
q
mean-1second = 0.004
a_n
mean-1second = 0.002
p
mean-1second = 0.007
r
mean-1second = 0.010
a_y
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Right Stabilator Failure: 10 runs
lf
mean-1second = 0.118
ls
mean-1second = 0.002
rs
mean-1second = 0.660
lf
mean-1second = 0.022
rf
mean-1second = 0.011
rud
mean-1second = 0.027
aoa
mean-1second = 0.052
q
mean-1second = 0.005
a_n
mean-1second = 0.010
p
mean-1second = 0.013
r
mean-1second = 0.079
a_y
mean-1second = 0.002
Time (sec)



Mean (+/– One Std Dev) Probabilities of Left Flaperon Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec)

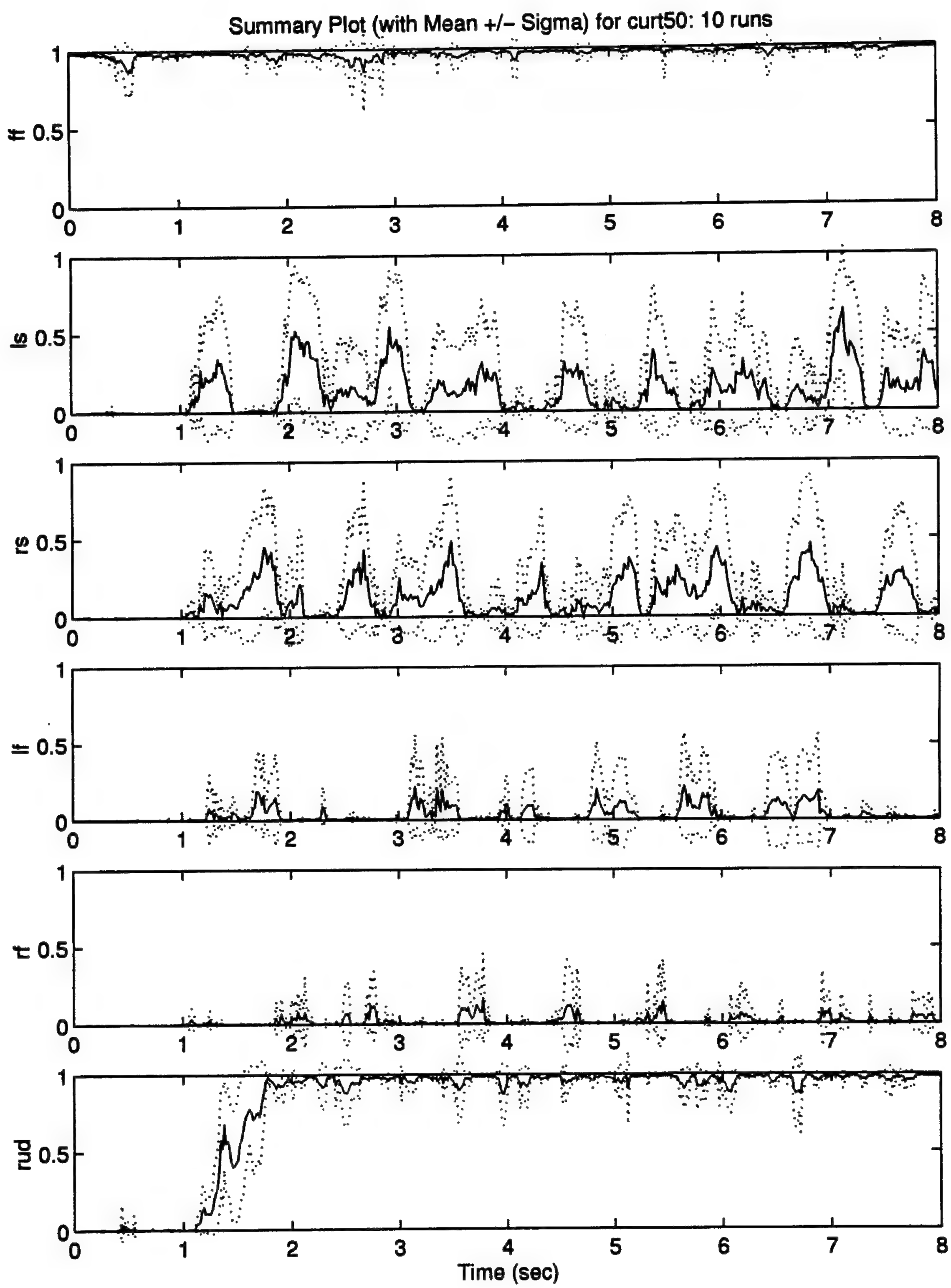

Mean (+/- One Std Dev) Probabilities of Right Flaperon Failure: 10 runs
rf
mean-1second = 0.301
ls
mean-1second = 0.003
rs
mean-1second = 0.003
lf
mean-1second = 0.003
rf
mean-1second = 0.584
rud
mean-1second = 0.004
aoa
mean-1second = 0.028
q
mean-1second = 0.005
a_n
mean-1second = 0.034
p
mean-1second = 0.016
r
mean-1second = 0.017
a_y
mean-1second = 0.002
Time (sec)

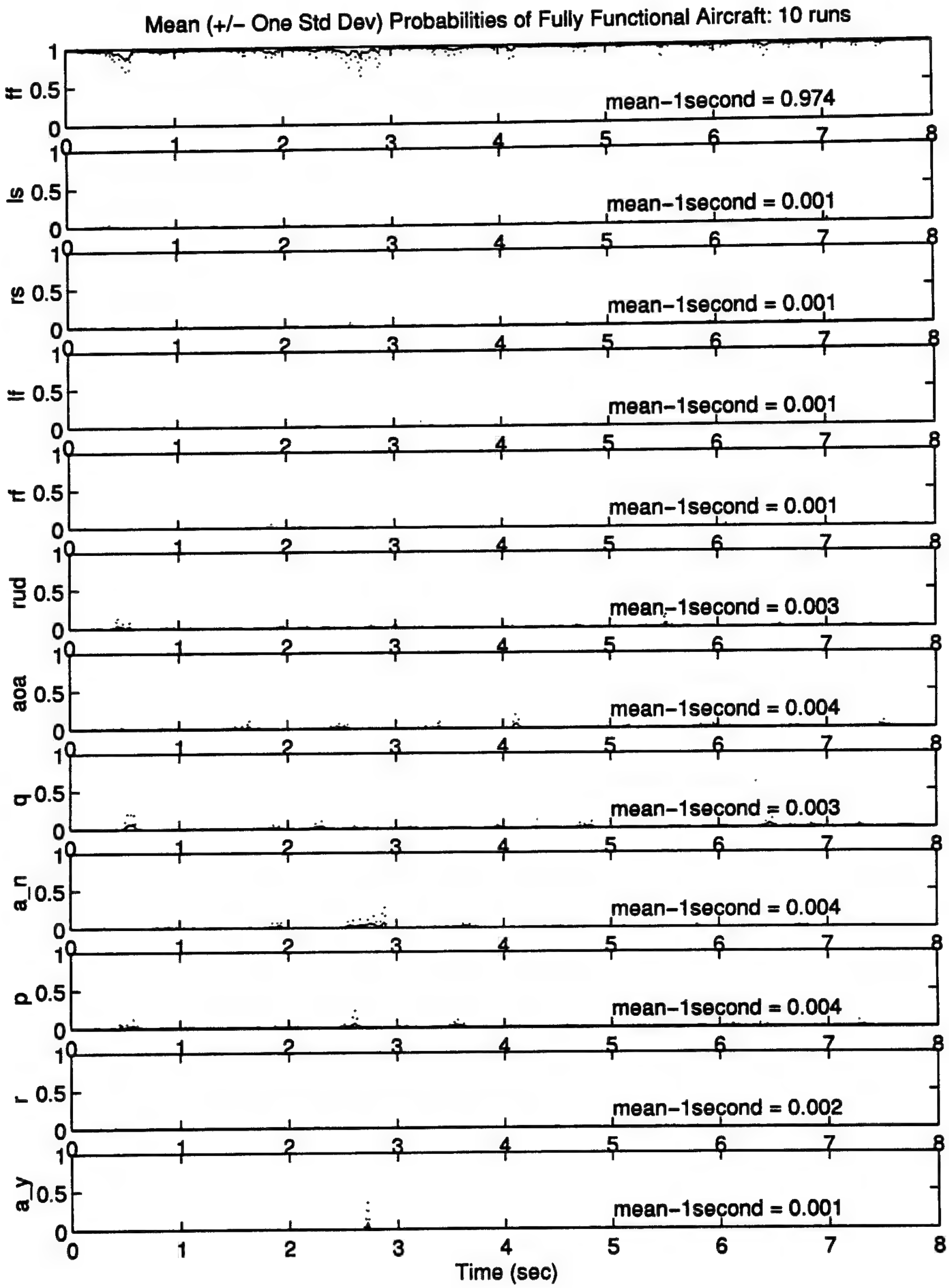


Mean (+/- One Std Dev) Probabilities of Rudder Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec)

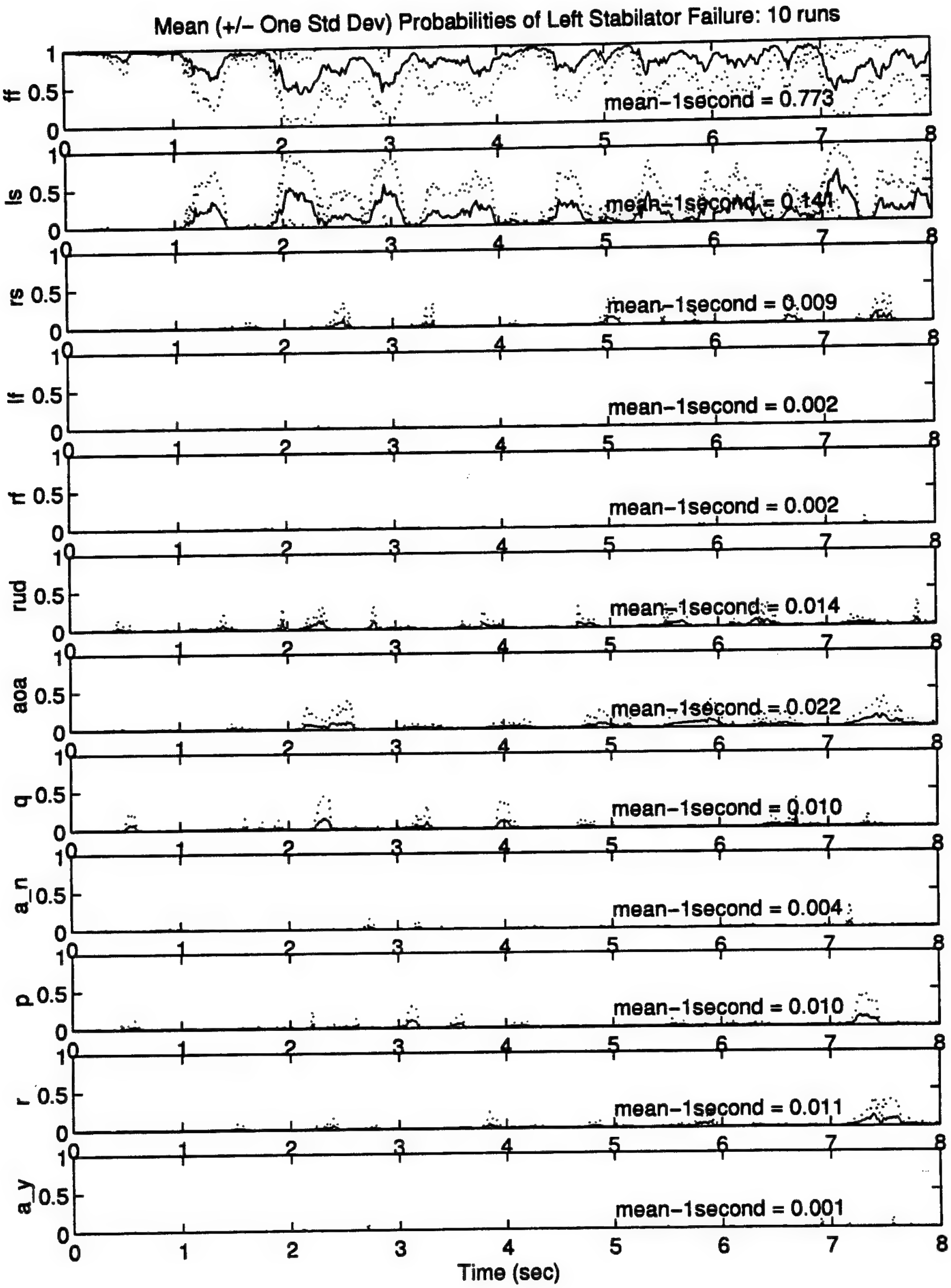
Appendix C.1: Single 50% Actuator Impairments (ε = .5), Control Redistribution 'OFF', Dither 'ON', No Maneuvers

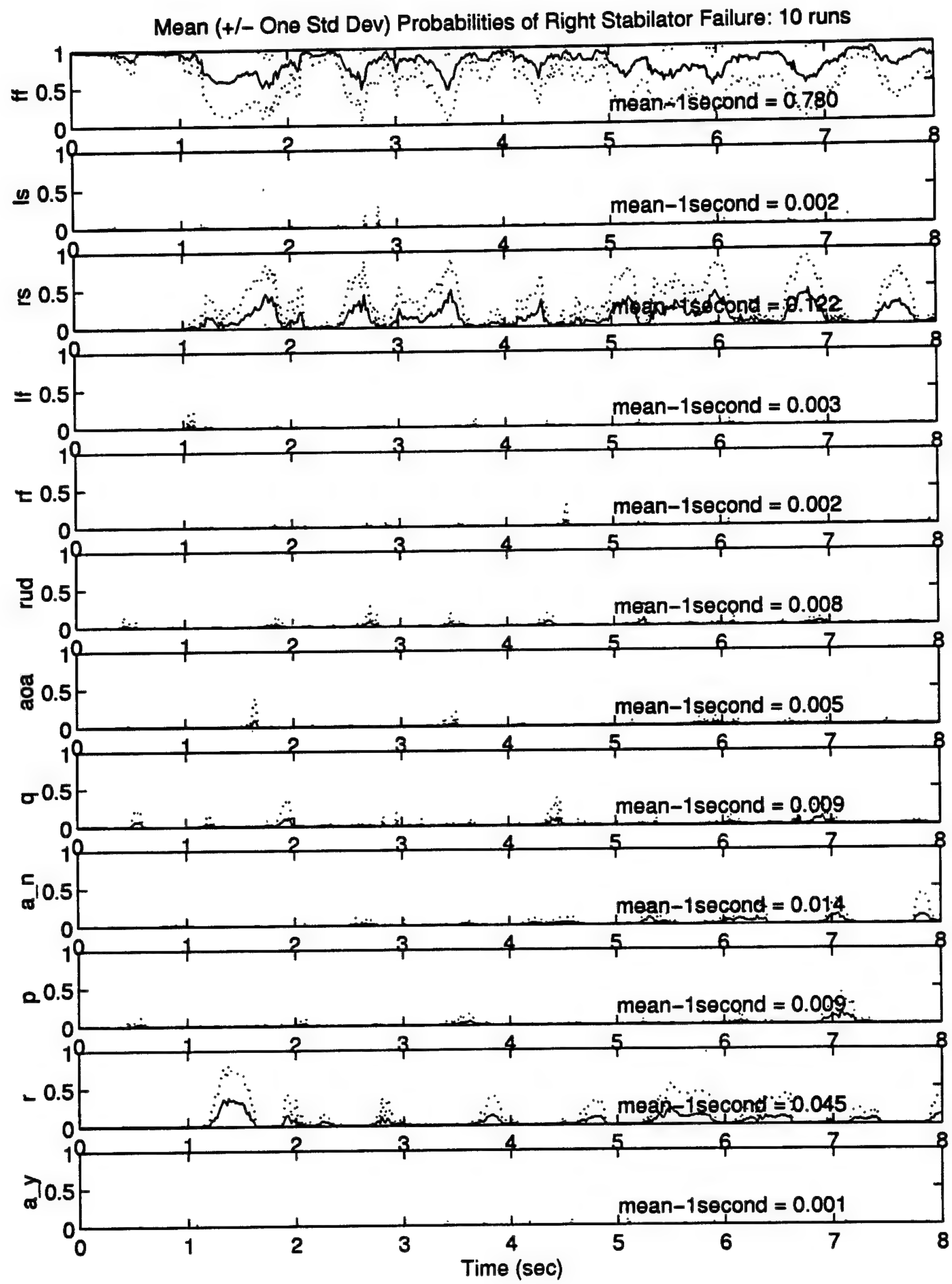
This appendix contains the Probability Summary Plot and individual probability plots for cases of single, 50% ($\varepsilon = .5$) actuator impairments, without aircraft maneuvering or Control Reconfiguration (Redistribution), but with control dithering (Section 4.13.1).

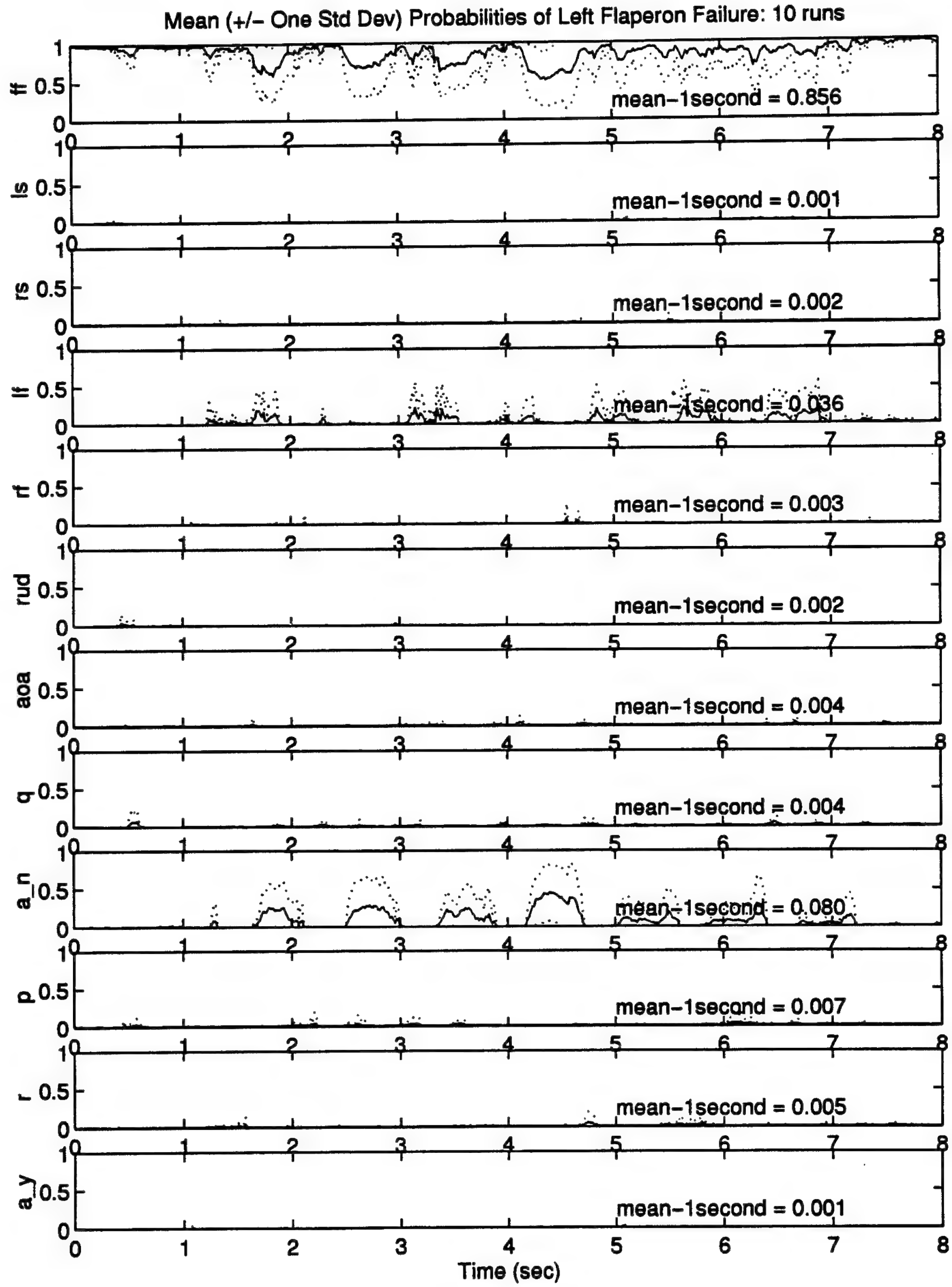

Summary Plot (with Mean +/- Sigma) for curt50: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)

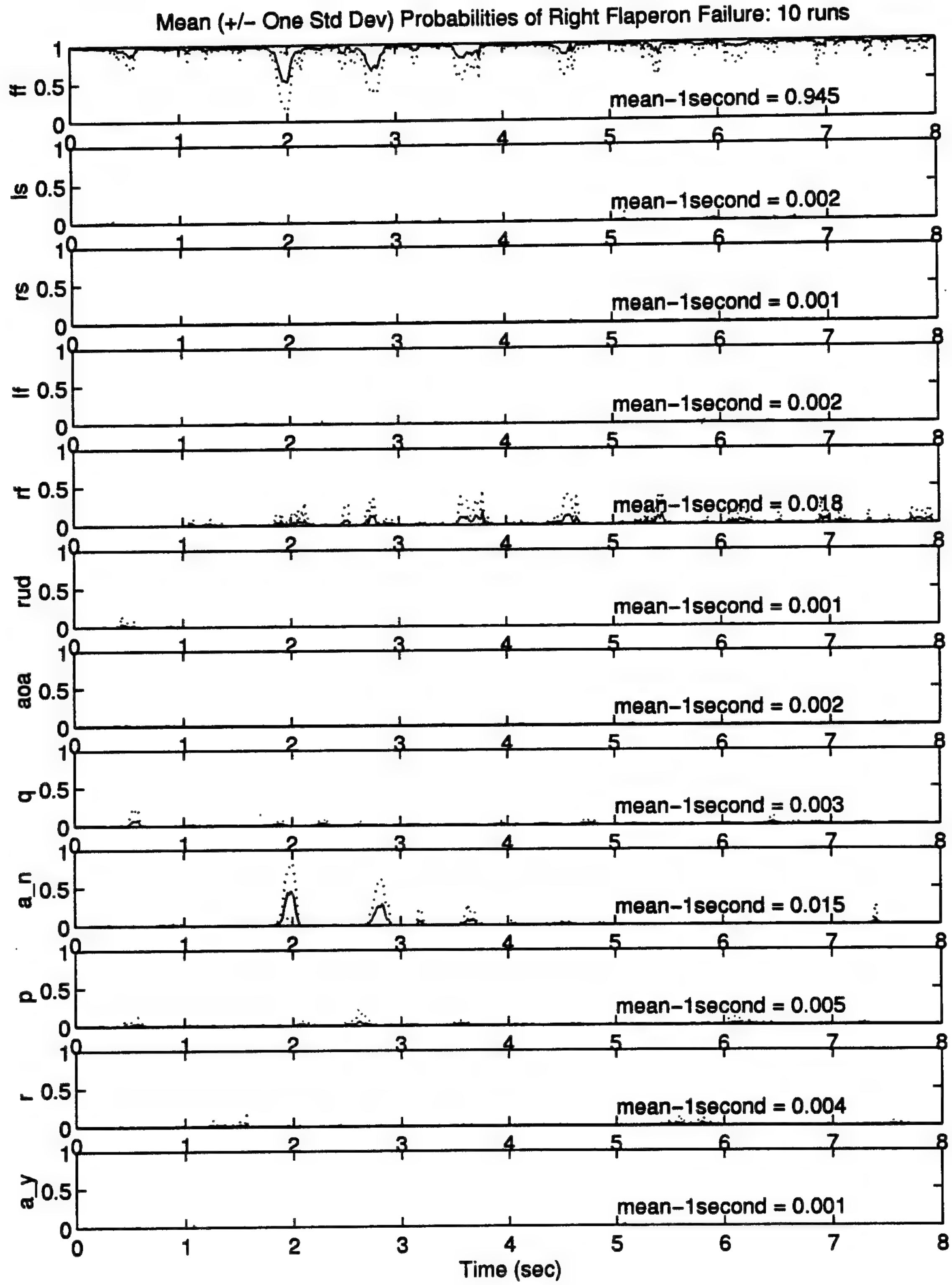


Mean (+/– One Std Dev) Probabilities of Fully Functional Aircraft: 10 runs
ff
mean–1second = 0.974
ls
mean–1second = 0.001
rs
mean–1second = 0.001
lf
mean–1second = 0.001
rf
mean–1second = 0.001
rud
mean–1second = 0.003
aoa
mean–1second = 0.004
q
mean–1second = 0.003
a_n
mean–1second = 0.004
p
mean–1second = 0.004
r
mean–1second = 0.002
a_y
mean–1second = 0.001
Time (sec)

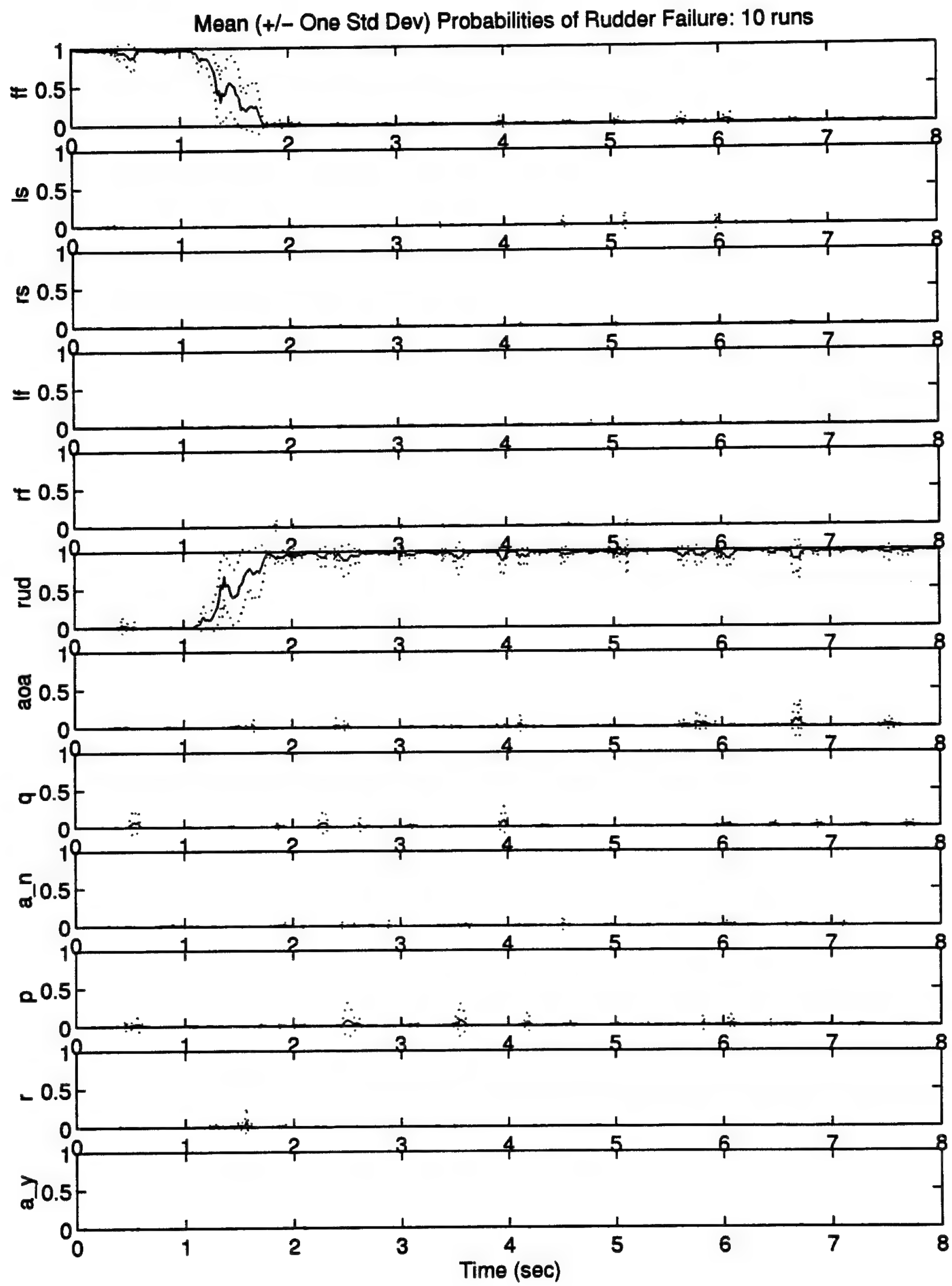

Mean (+/- One Std Dev) Probabilities of Left Stabilator Failure: 10 runs
ff
mean-1second = 0.773
ls
mean-1second = 0.141
rs
mean-1second = 0.009
lf
mean-1second = 0.002
rf
mean-1second = 0.002
rud
mean-1second = 0.014
aoa
mean-1second = 0.022
q
mean-1second = 0.010
a_n
mean-1second = 0.004
p
mean-1second = 0.010
r
mean-1second = 0.011
a_y
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Right Stabilator Failure: 10 runs
ff
mean-1second = 0.780
ls
mean-1second = 0.002
rs
mean-1second = 0.122
lf
mean-1second = 0.003
rf
mean-1second = 0.002
rud
mean-1second = 0.008
aoa
mean-1second = 0.005
q
mean-1second = 0.009
a_n
mean-1second = 0.014
p
mean-1second = 0.009
r
mean-1second = 0.045
a_y
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Left Flaperon Failure: 10 runs
ff
mean-1second = 0.856
ls
mean-1second = 0.001
rs
mean-1second = 0.002
lf
mean-1second = 0.036
rf
mean-1second = 0.003
rud
mean-1second = 0.002
aoa
mean-1second = 0.004
q
mean-1second = 0.004
a_n
mean-1second = 0.080
p
mean-1second = 0.007
r
mean-1second = 0.005
a_y
mean-1second = 0.001
Time (sec)



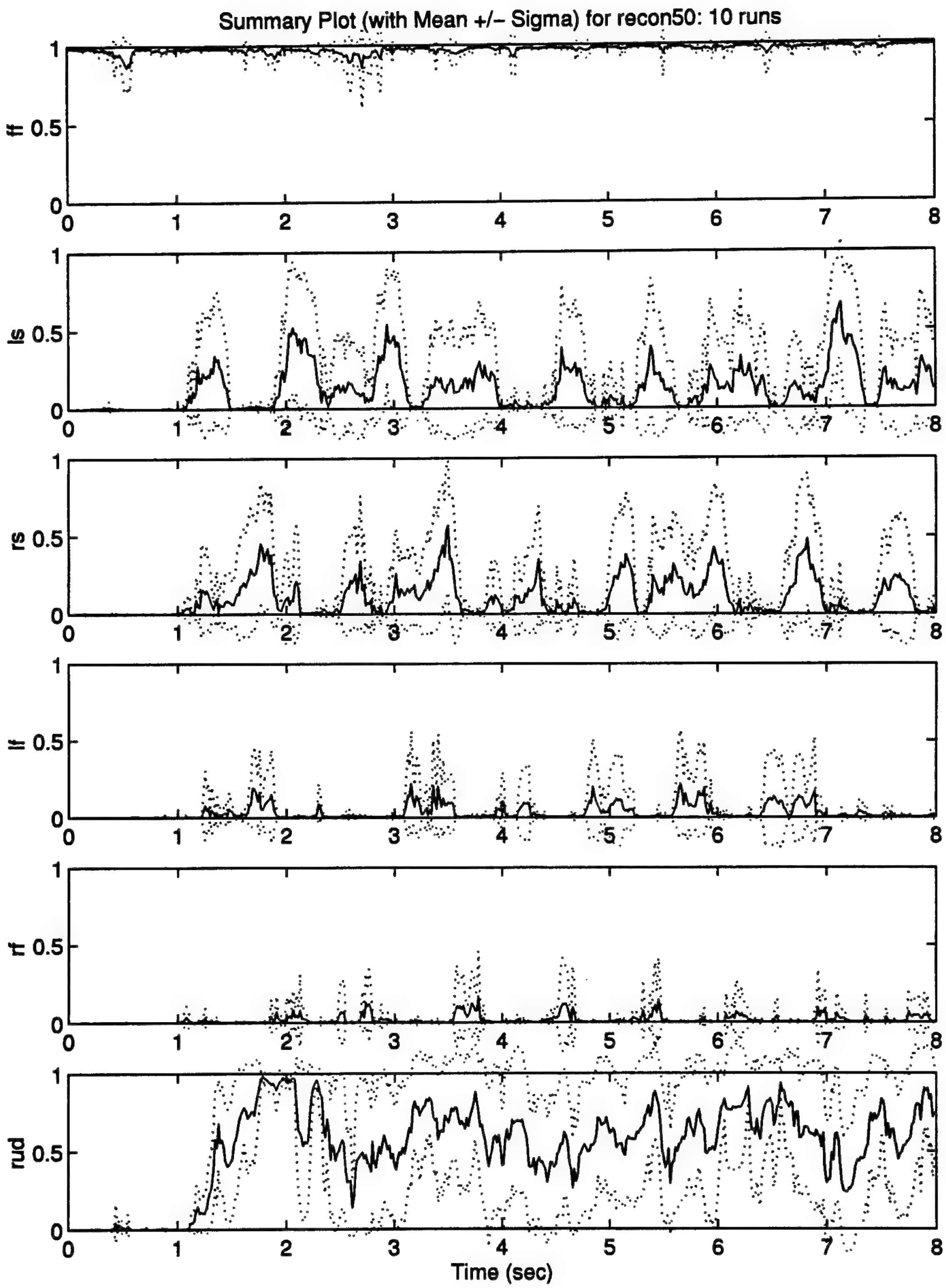
Mean (+/- One Std Dev) Probabilities of Right Flaperon Failure: 10 runs
ff
mean-1second = 0.945
ls
mean-1second = 0.002
rs
mean-1second = 0.001
lf
mean-1second = 0.002
rf
mean-1second = 0.018
rud
mean-1second = 0.001
aoa
mean-1second = 0.002
q
mean-1second = 0.003
a_n
mean-1second = 0.015
p
mean-1second = 0.005
r
mean-1second = 0.004
a_y
mean-1second = 0.001
Time (sec)



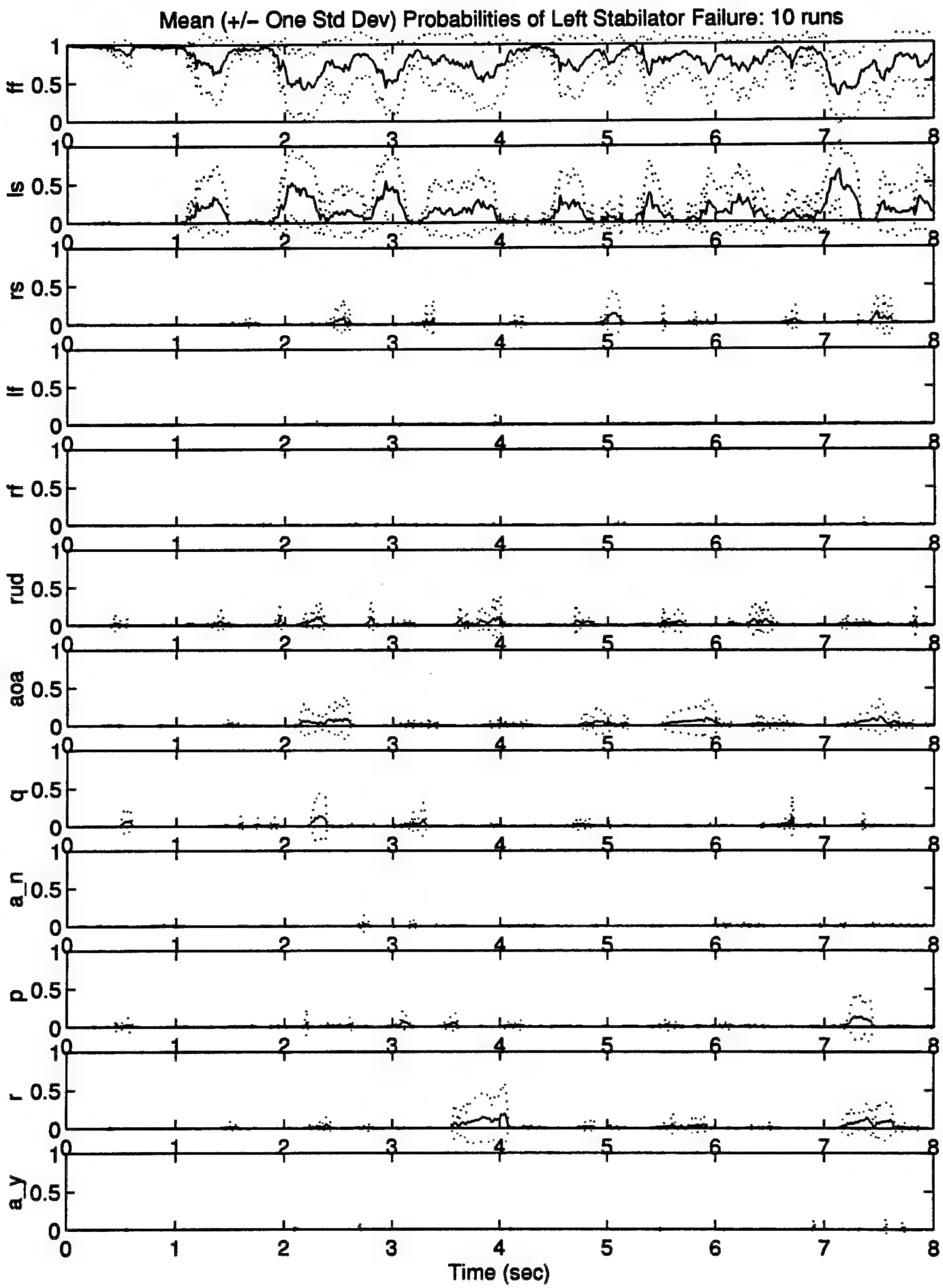
Mean (+/– One Std Dev) Probabilities of Rudder Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec)

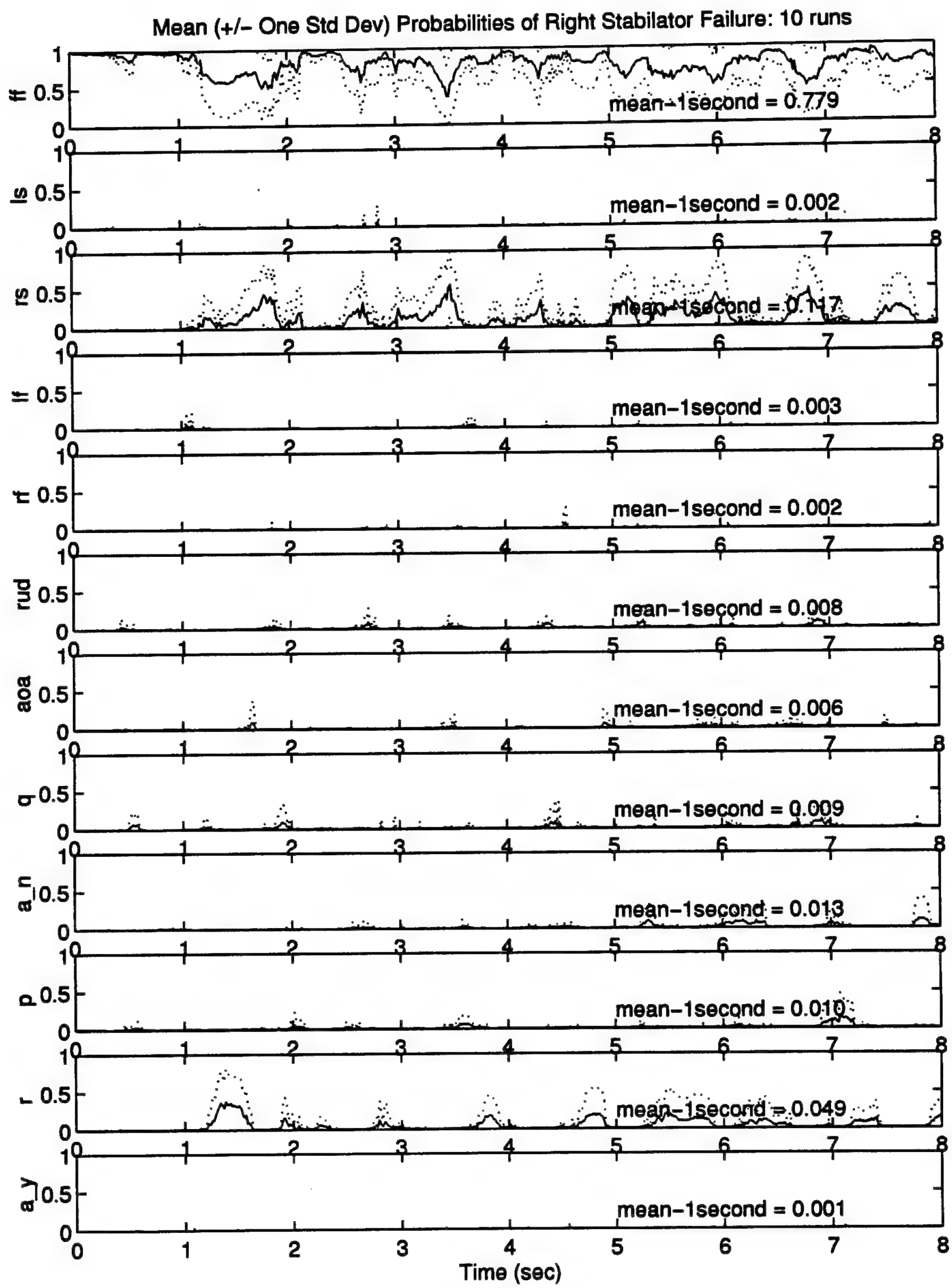
Appendix C.2: Single 50% Actuator Impairments ($\varepsilon = .5$), Control Redistribution 'ON', Dither 'ON', No Maneuvers

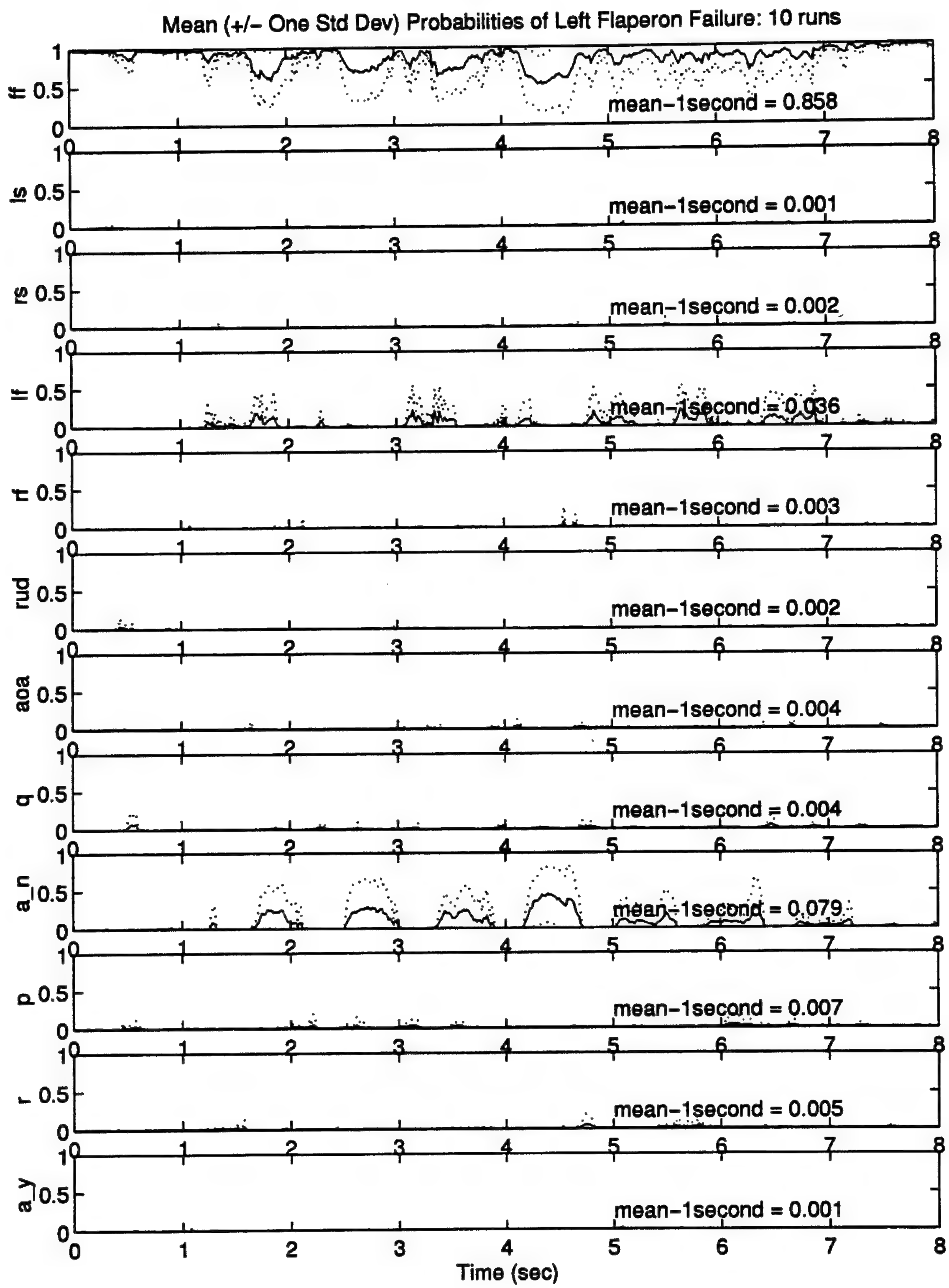
This appendix contains the Probability Summary Plot and individual probability plots for cases of single, 50% ($\varepsilon = .5$) actuator impairments, without aircraft maneuvering, but with Control Reconfiguration (Redistribution), and with control dithering (Section 4.13.2).

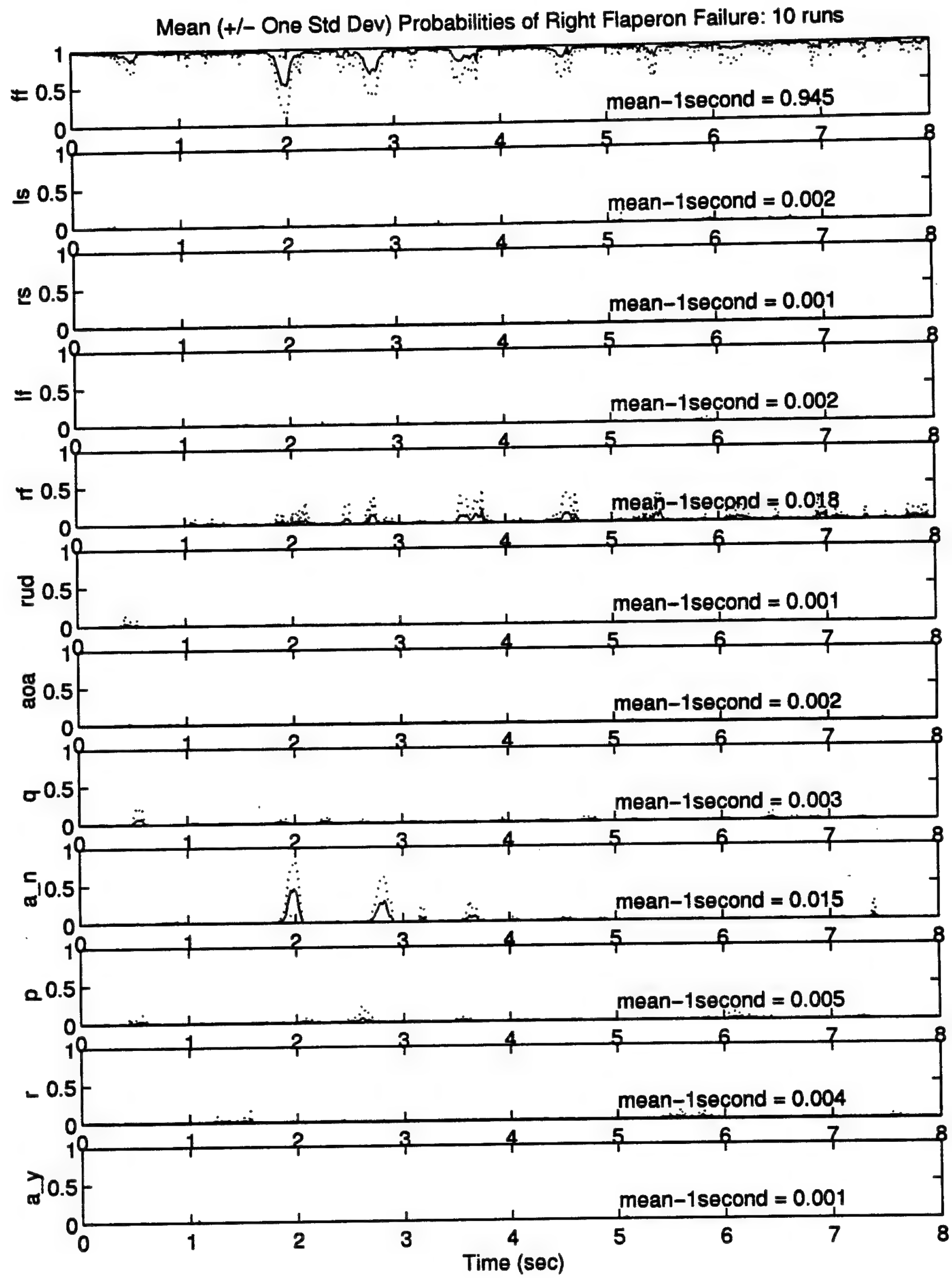


Summary Plot (with Mean +/- Sigma) for recon50: 10 runs
ff
ls
rs
lf
rf
rud
Time (sec)

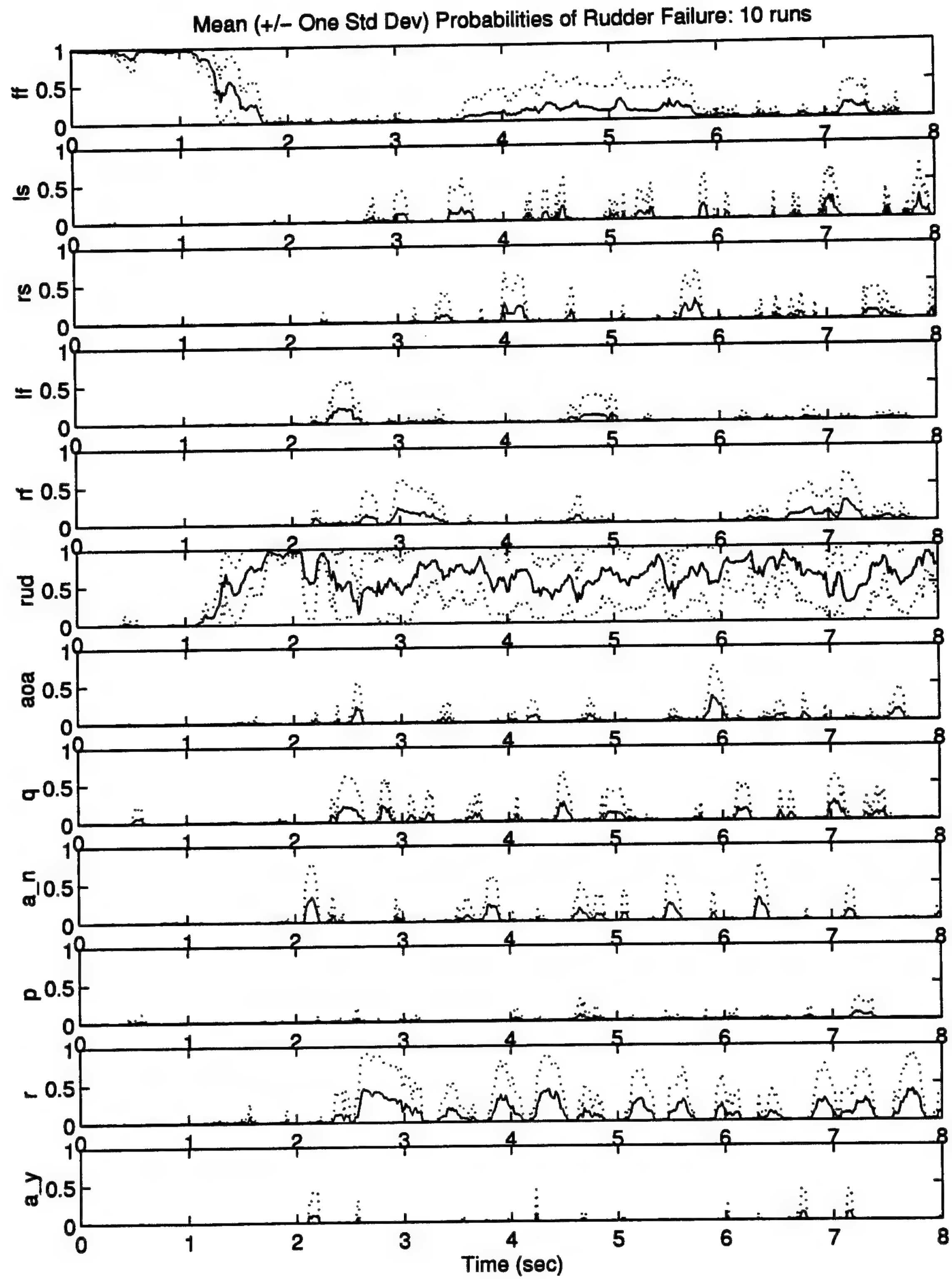

Mean (+/- One Std Dev) Probabilities of Left Stabilator Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec)


Mean (+/- One Std Dev) Probabilities of Right Stabilator Failure: 10 runs
ff
mean-1second = 0.779
ls
mean-1second = 0.002
rs
mean-1second = 0.117
lf
mean-1second = 0.003
rf
mean-1second = 0.002
rud
mean-1second = 0.008
aoa
mean-1second = 0.006
q
mean-1second = 0.009
a_n
mean-1second = 0.013
p
mean-1second = 0.010
r
mean-1second = 0.049
a_y
mean-1second = 0.001
Time (sec)


Mean (+/- One Std Dev) Probabilities of Left Flaperon Failure: 10 runs
lf
mean-1second = 0.858
ls
mean-1second = 0.001
rs
mean-1second = 0.002
lf
mean-1second = 0.036
rf
mean-1second = 0.003
rud
mean-1second = 0.002
aoa
mean-1second = 0.004
q
mean-1second = 0.004
a_n
mean-1second = 0.079
p
mean-1second = 0.007
r
mean-1second = 0.005
a_y
mean-1second = 0.001
Time (sec)



Mean (+/- One Std Dev) Probabilities of Right Flaperon Failure: 10 runs
ff
mean-1second = 0.945
ls
mean-1second = 0.002
rs
mean-1second = 0.001
lf
mean-1second = 0.002
rf
mean-1second = 0.018
rud
mean-1second = 0.001
aoa
mean-1second = 0.002
q
mean-1second = 0.003
a_n
mean-1second = 0.015
p
mean-1second = 0.005
r
mean-1second = 0.004
a_y
mean-1second = 0.001
Time (sec)



Mean (+/- One Std Dev) Probabilities of Rudder Failure: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec)

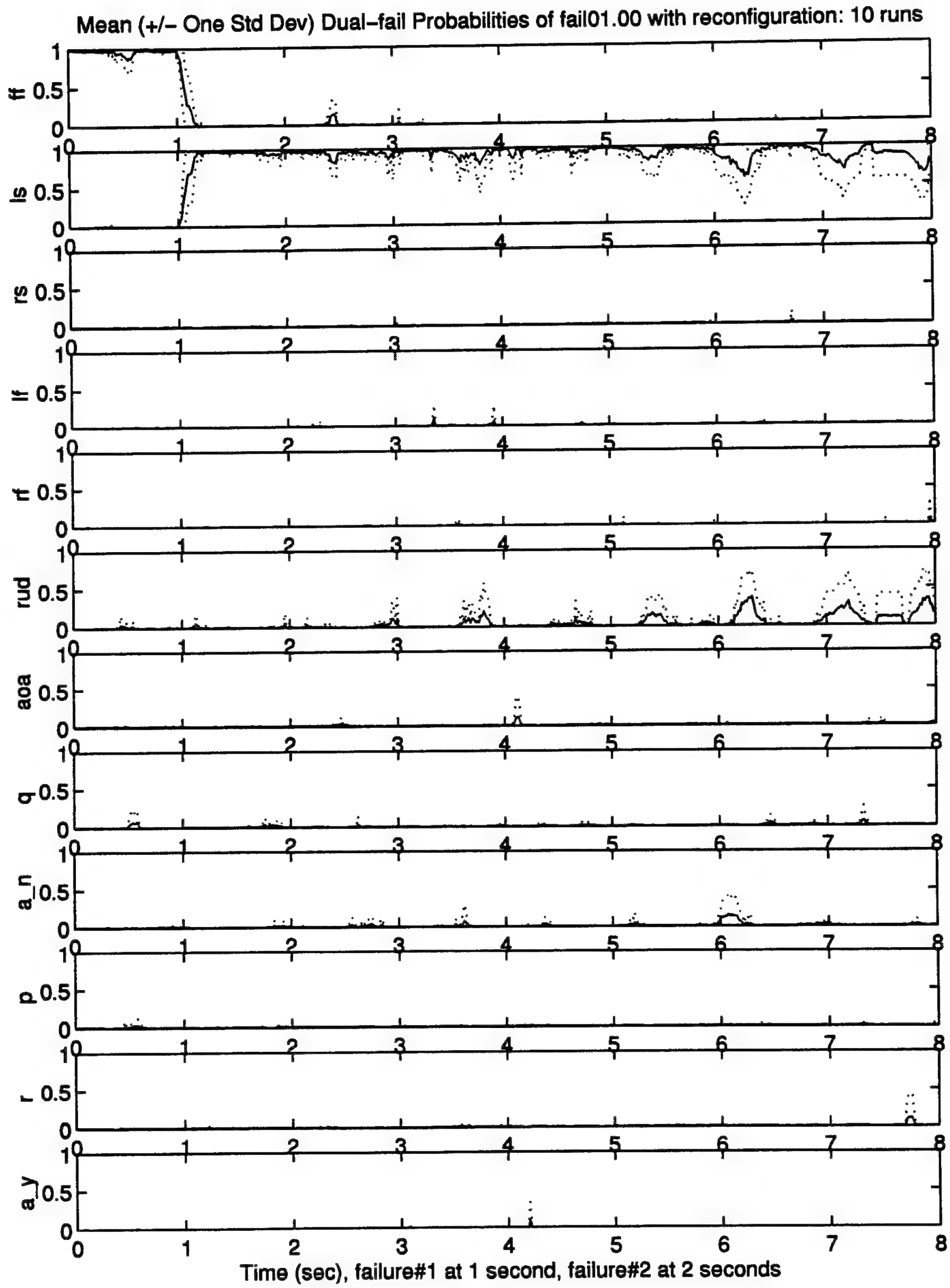
Appendix D.1: Dual, Total Actuator ($\varepsilon = 0$) and Total-Actuator / Total -Sensor Impairments, Control Redistribution 'ON', Dither 'ON', No Maneuvers

This appendix contains the individual probability plots for "total actuator / total actuator" and "total actuator / total sensor" dual impairment scenarios, *with* Control Reconfiguration (Redistribution) and with control dithering (Section 4.11.3). The first impairment is inserted at 1 second, followed by the second impairment at 2 seconds, and in all cases, there is no aircraft maneuvering. Table D.1 on the following page lists the impairment cases, by case number, which are to be found in this appendix. The leftmost column of Table D.1 represents the first impairment occurring at 1 second, while the top row represents the second impairment occurring at 2 seconds. The table entries list the failure codes found in the plot titles for the failure case represented by the table row and column. **Bold** entries correspond to cases of no second impairment. As an example, the entry for a left stabilator (LS) impairment at 1 second, followed by a right flaperon (RF) impairment at 2 seconds is found in entry '(LS, RF)' in the table, and the corresponding failure case is 'fail01.04'. The probability plot will contain this code ('fail01.04') in the plot title. In fact, for this specific case, the plot title is: "Mean (+ / - One Std Dev) Dual-fail Probabilities of fail01.04 with reconfiguration: 10 runs". The reader should not be confused by the fact that, for cases of total sensor second impairments, there is an extra set of zeros (example: 'fail001.006' vs. 'fail01.06', as one may anticipate) in the failure code. The dual, *total* actuator impairment cases were run at an earlier date, before the additional zero placeholders were added to the plotting routine to provide for meaningful plot titles during *partial* impairment scenarios to come. The reader is also reminded that, after the switch to the Level '1' filter bank, the meanings of the probability traces in the plots (except for the fully functional trace, which retains the same meaning) change to that of the first impairment *plus* the second impairment.

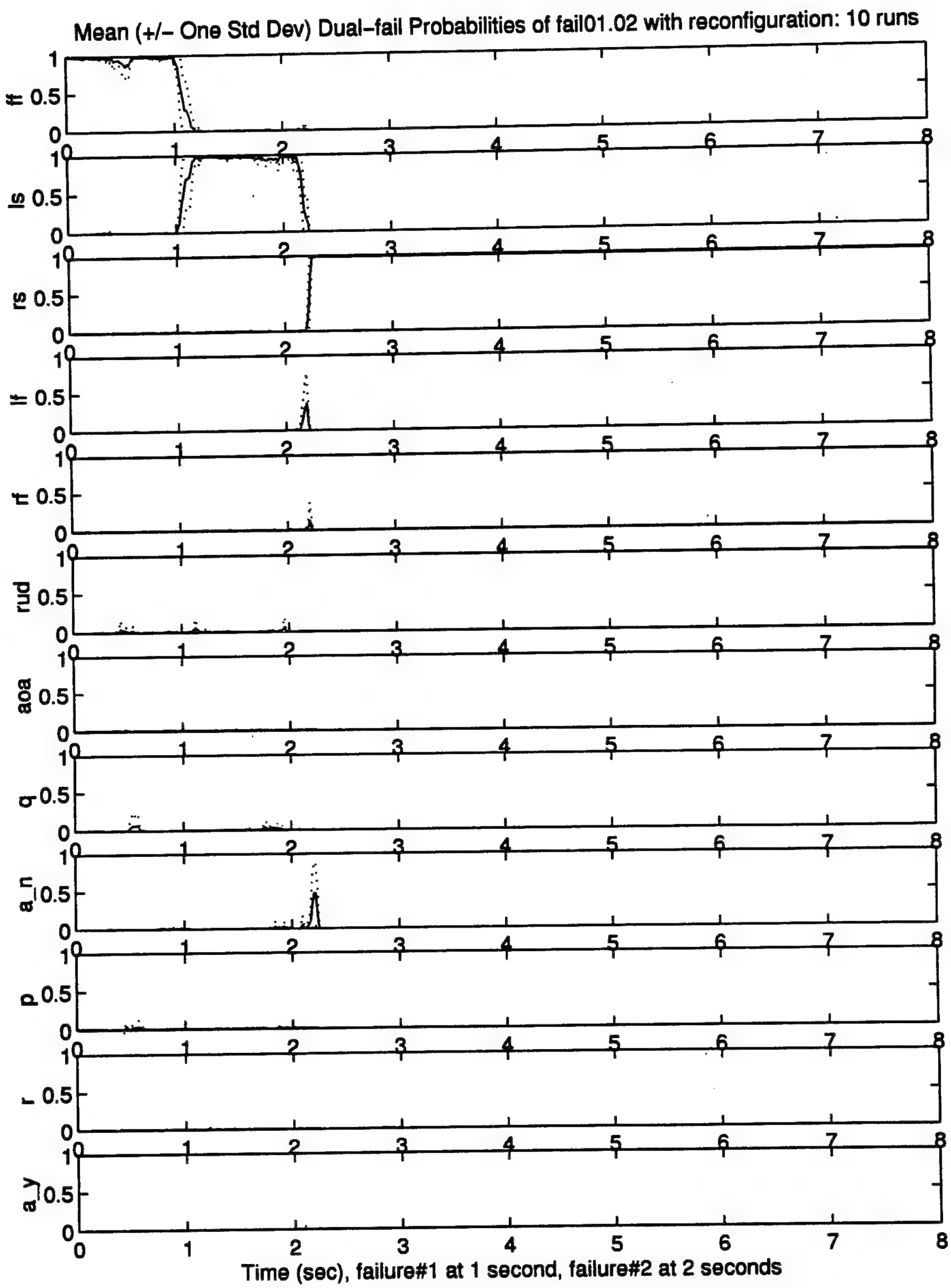
Second Impairment

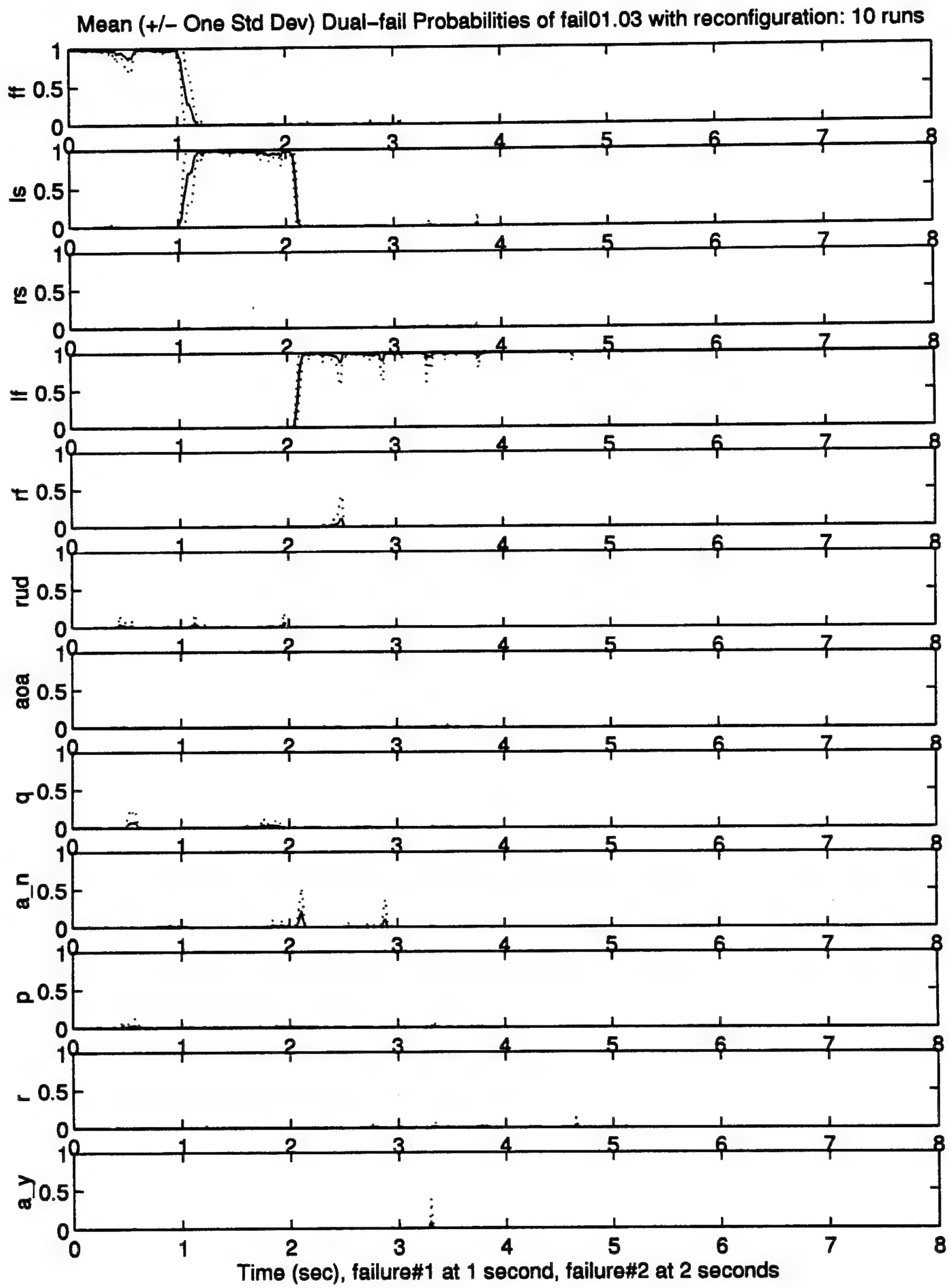
	LS (100%)	RS (100%)	LF (100%)	RF (100%)	RUD (100%)	AOA (100%)	Q (100%)	A_n (100%)	P (100%)	R (100%)	A_y (100%)
LS (100%)	**fail01.00**	fail01.02	fail01.03	fail01.04	fail01.05	fail001.006	fail001.007	fail001.008	fail001.009	fail001.0010	fail001.0011
RS (100%)	fail02.01	**fail02.00**	fail02.03	fail02.04	fail02.05	fail002.006	fail002.007	fail002.008	fail002.009	fail002.0010	fail002.0011
LF (100%)	fail03.01	fail03.02	**fail03.00**	fail03.04	fail03.05	fail003.006	fail003.007	fail003.008	fail003.009	fail003.0010	fail003.0011
RF (100%)	fail04.01	fail04.02	fail04.03	**fail04.00**	fail04.05	fail004.006	fail004.007	fail004.008	fail004.009	fail004.0010	fail004.0011
RUD (100%)	fail05.01	fail05.02	fail05.03	fail05.04	**fail05.00**	fail005.006	fail005.007	fail005.008	fail005.009	fail005.0010	fail005.0011

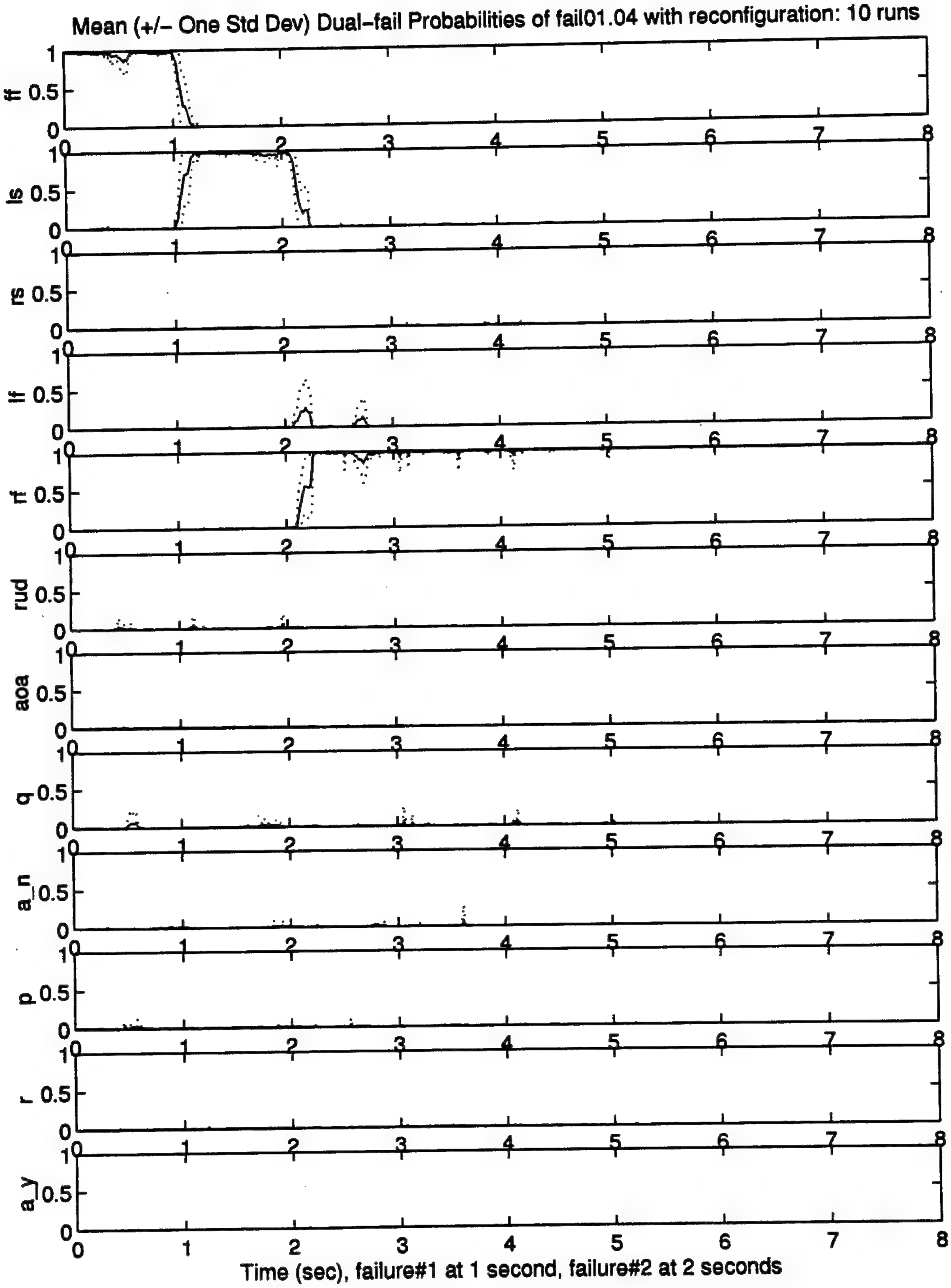
Table D.1 A Listing of All Probability Plots Found in Appendix D.1 by Failure Case

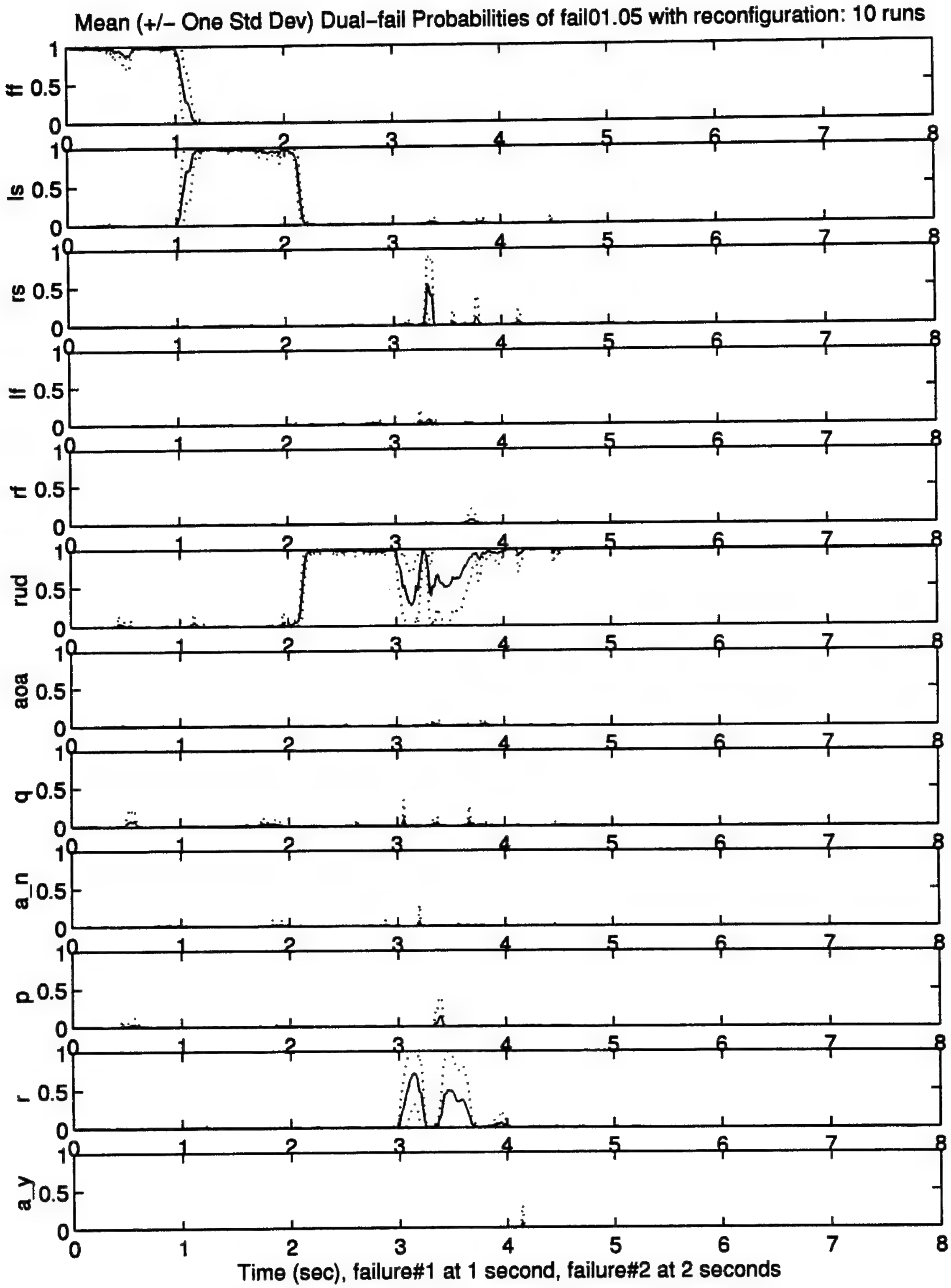


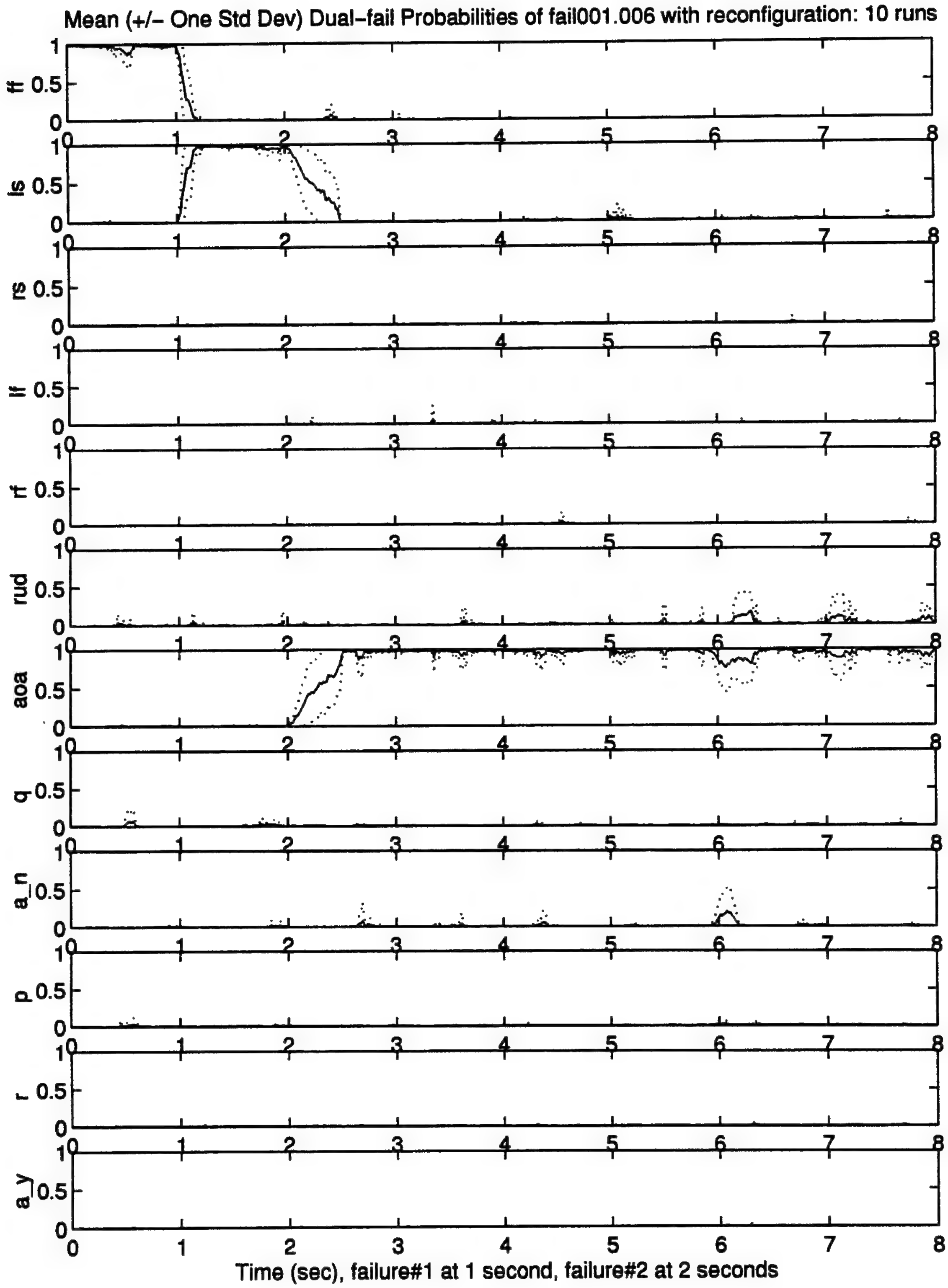
Mean (+/- One Std Dev) Dual-fail Probabilities of fail01.00 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail01.02 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

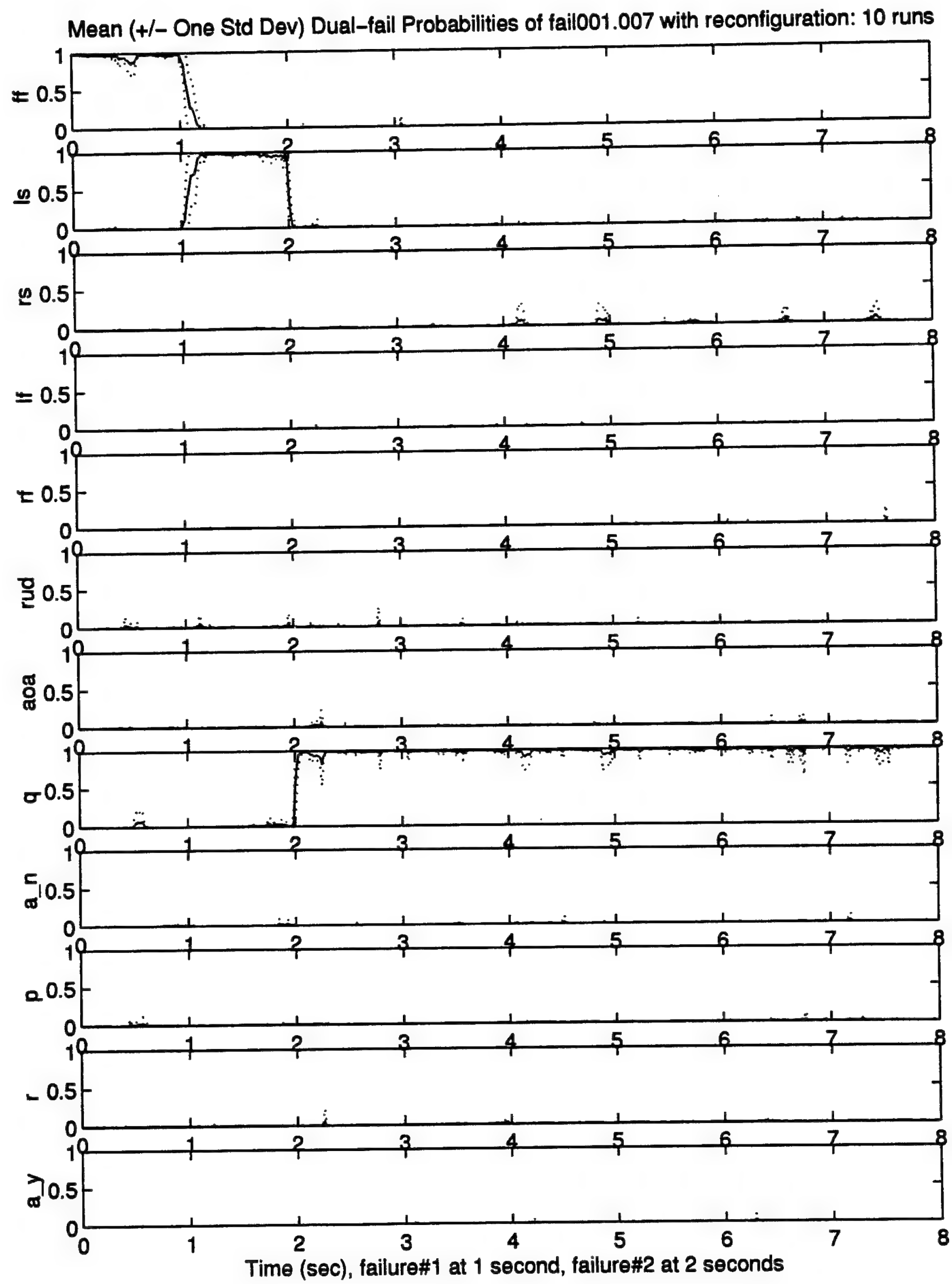

Mean (+/- One Std Dev) Dual-fail Probabilities of fail01.03 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

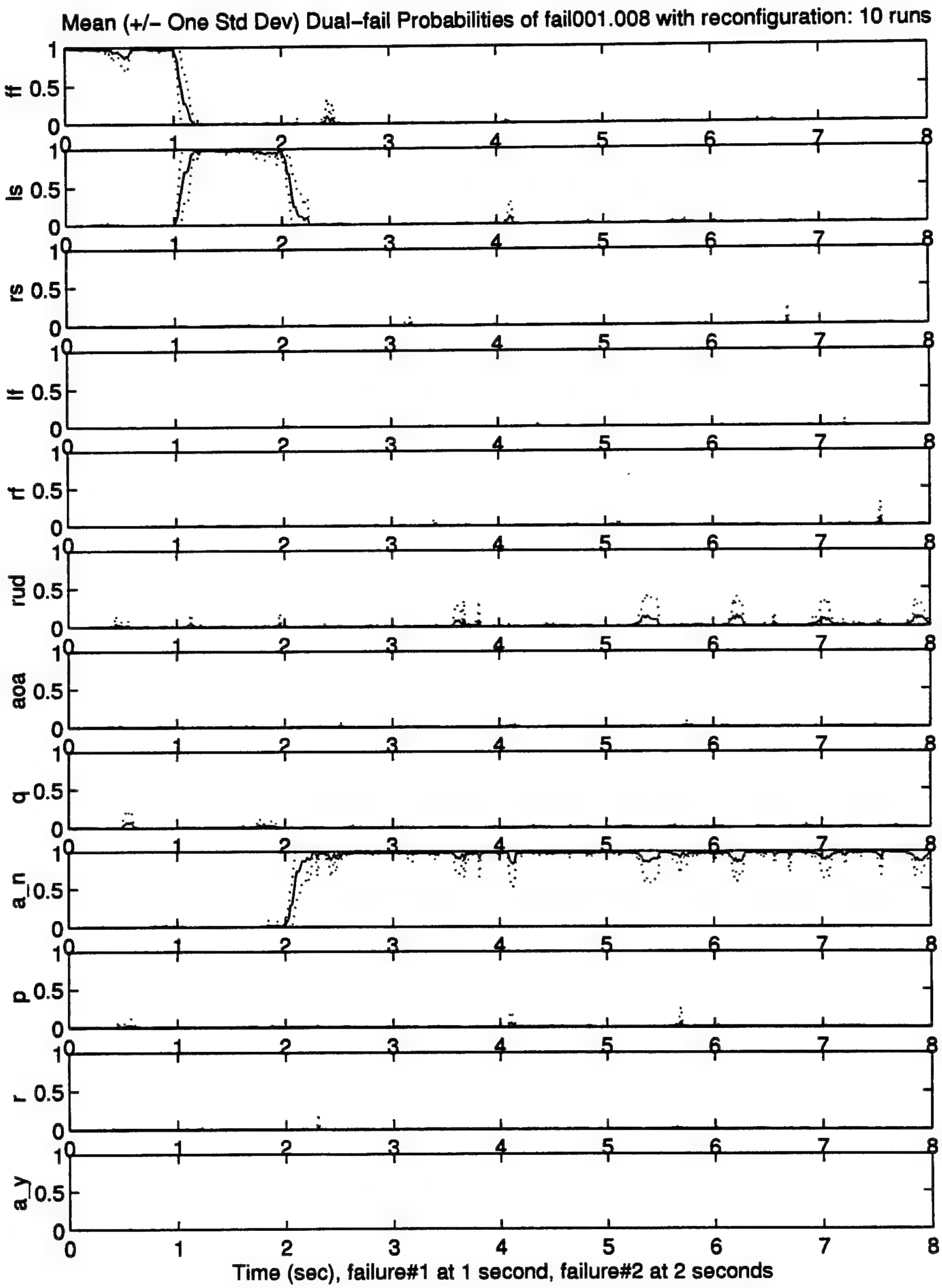

Mean (+/- One Std Dev) Dual-fail Probabilities of fail01.04 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail01.05 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

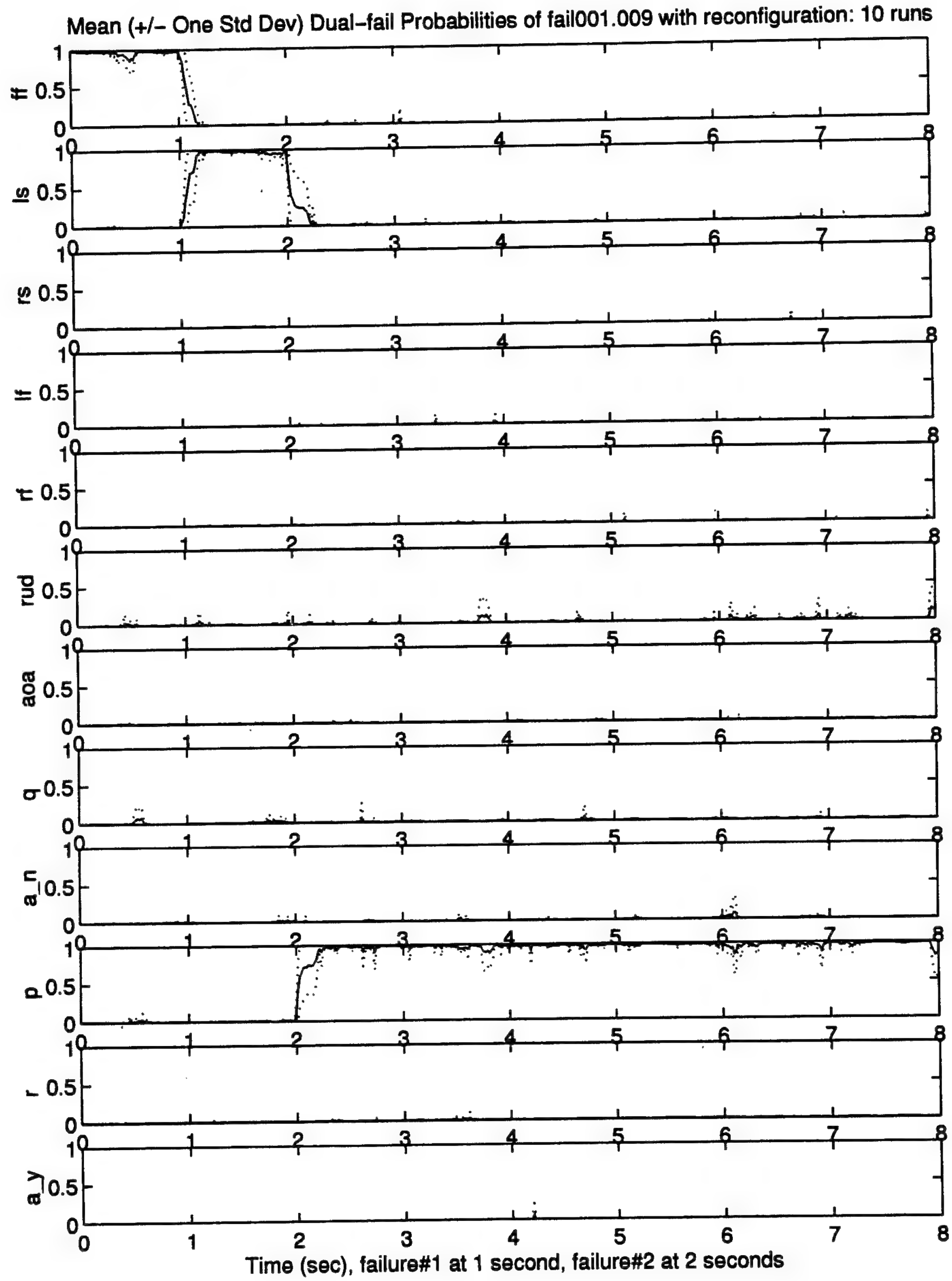


Mean (+/- One Std Dev) Dual-fail Probabilities of fail001.006 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

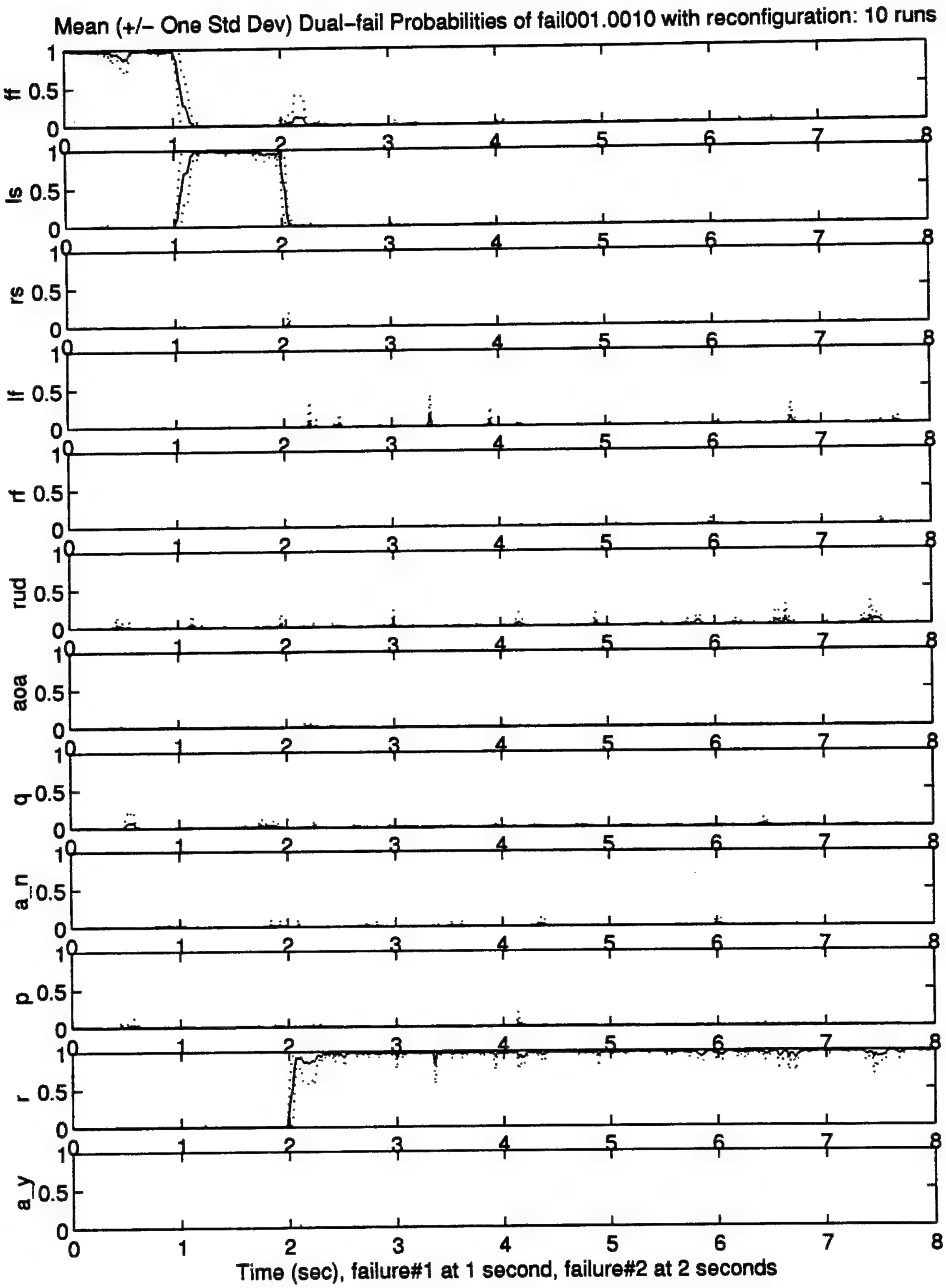

Mean (+/- One Std Dev) Dual-fail Probabilities of fail001.007 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



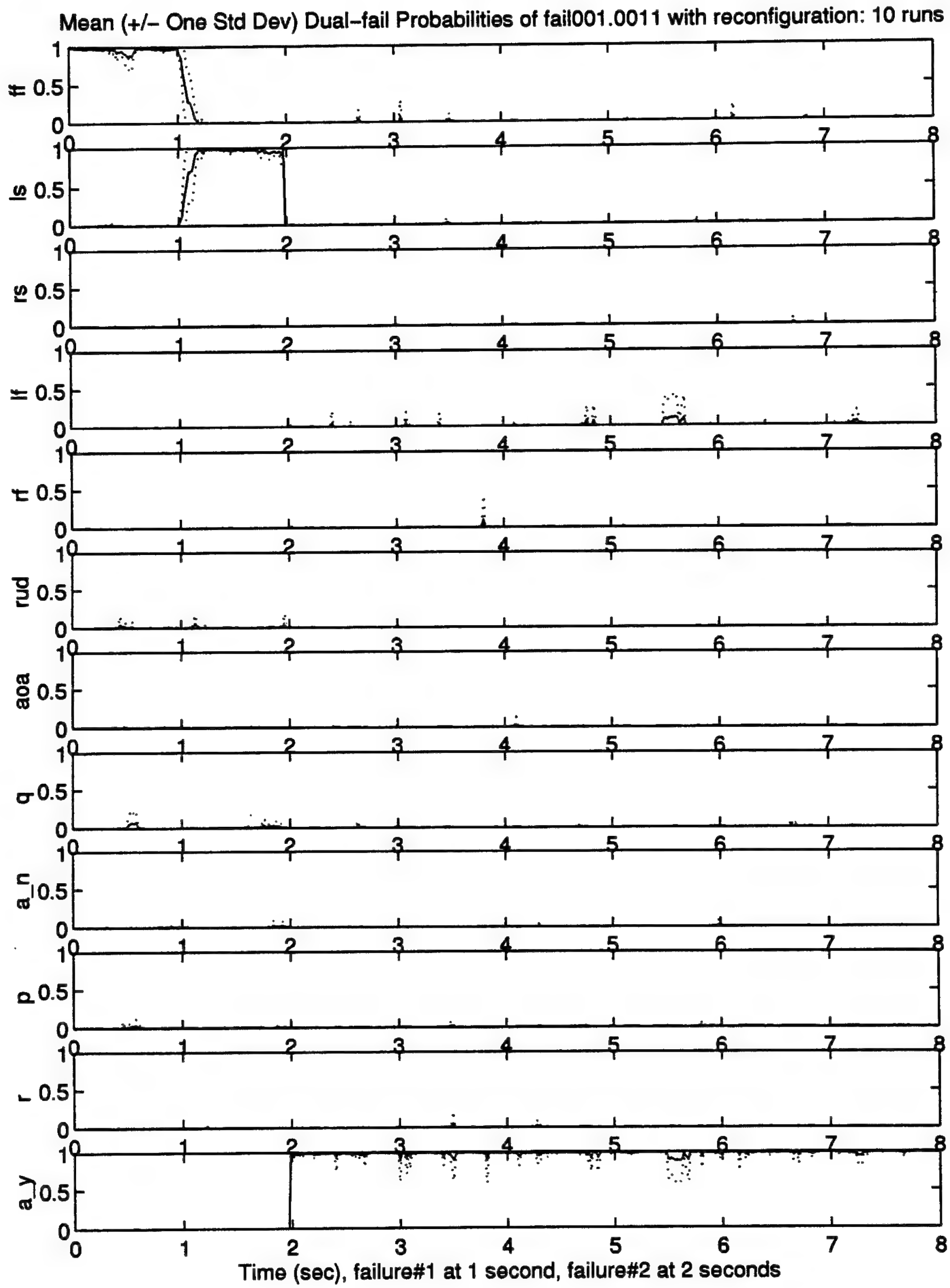
Mean (+/- One Std Dev) Dual-fail Probabilities of fail001.008 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



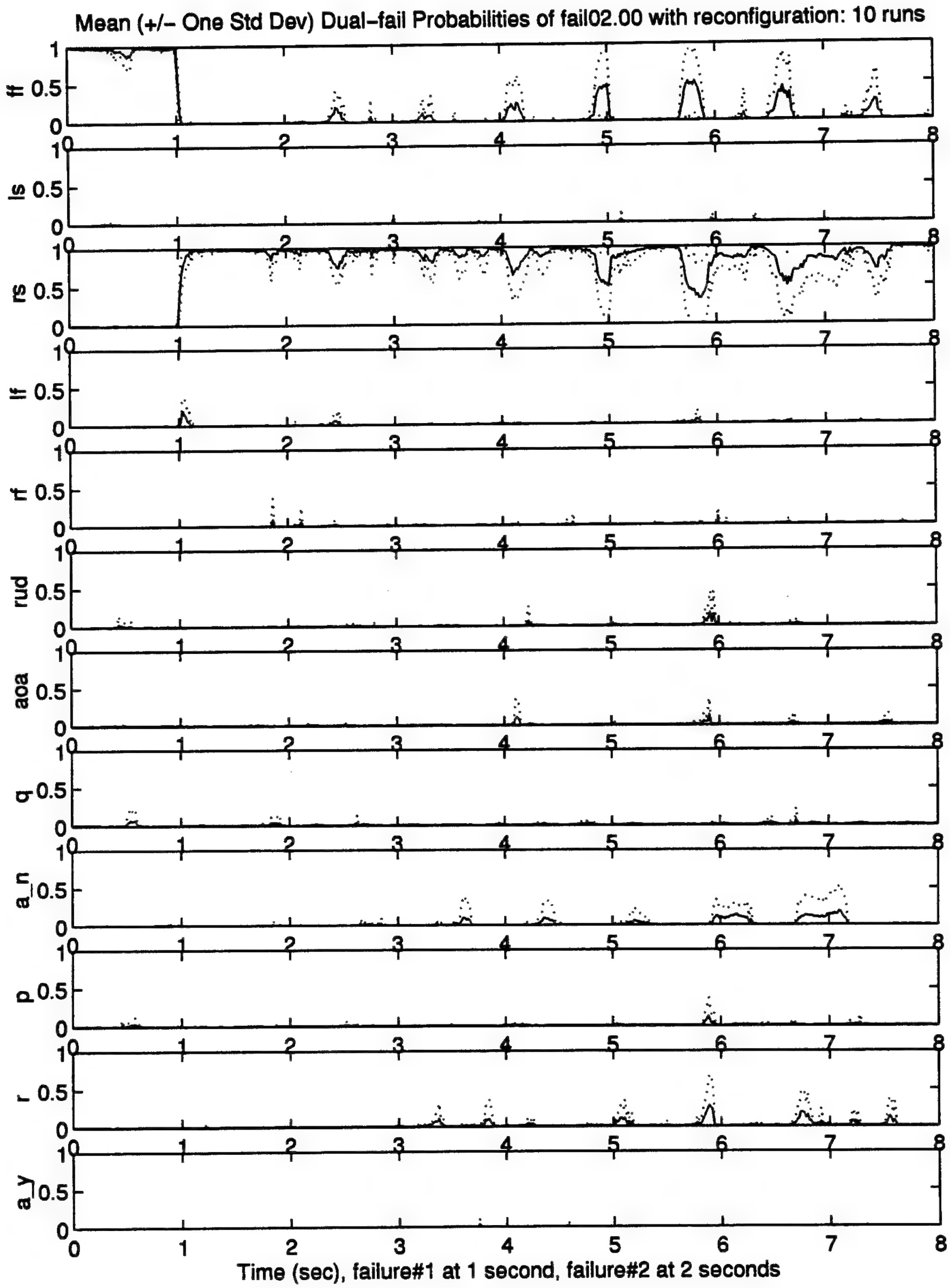
Mean (+/- One Std Dev) Dual-fail Probabilities of fail001.009 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

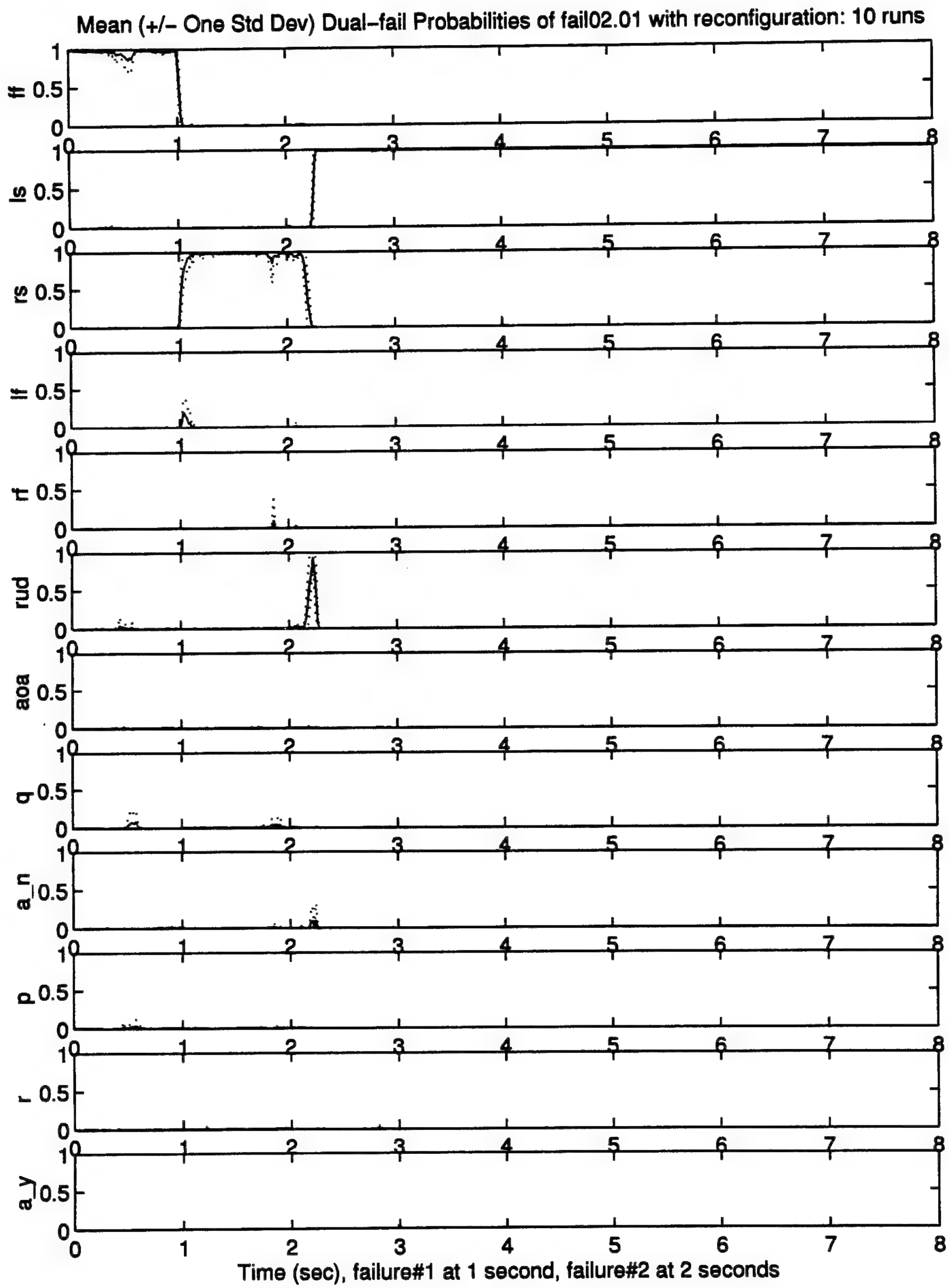


Mean (+/- One Std Dev) Dual-fail Probabilities of fail001.0010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

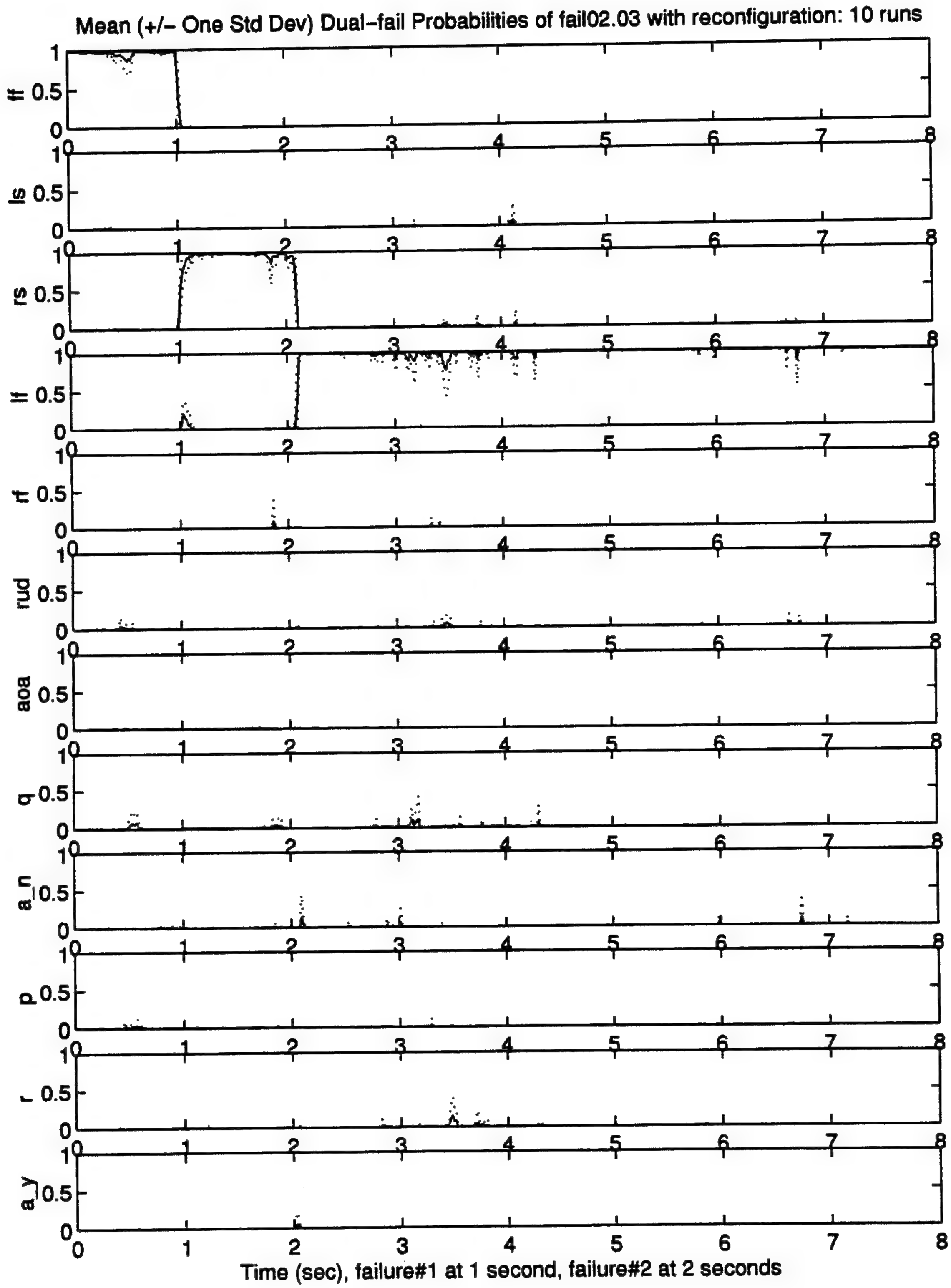


Mean (+/– One Std Dev) Dual–fail Probabilities of fail001.0011 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

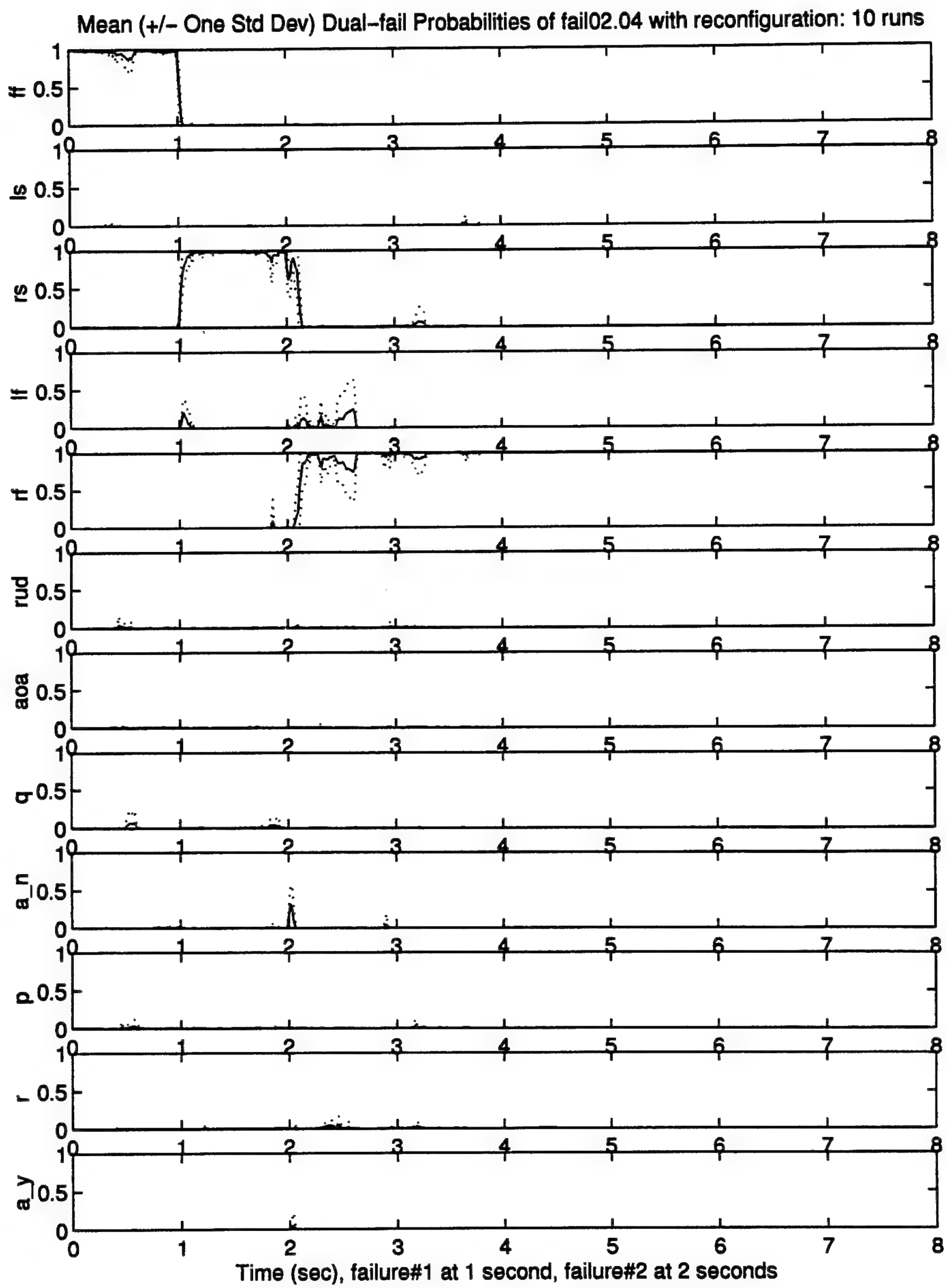

Mean (+/- One Std Dev) Dual-fail Probabilities of fail02.00 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

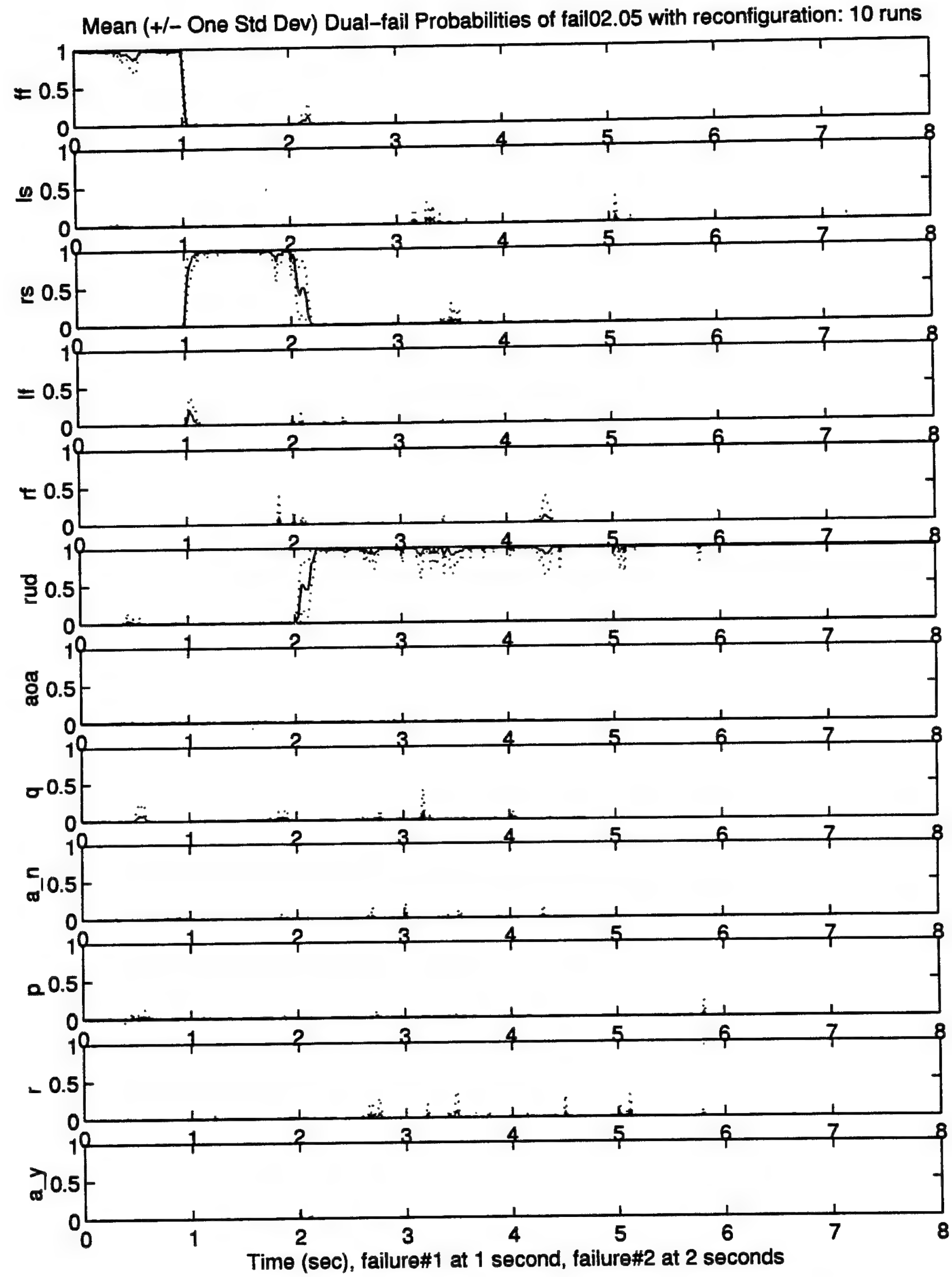


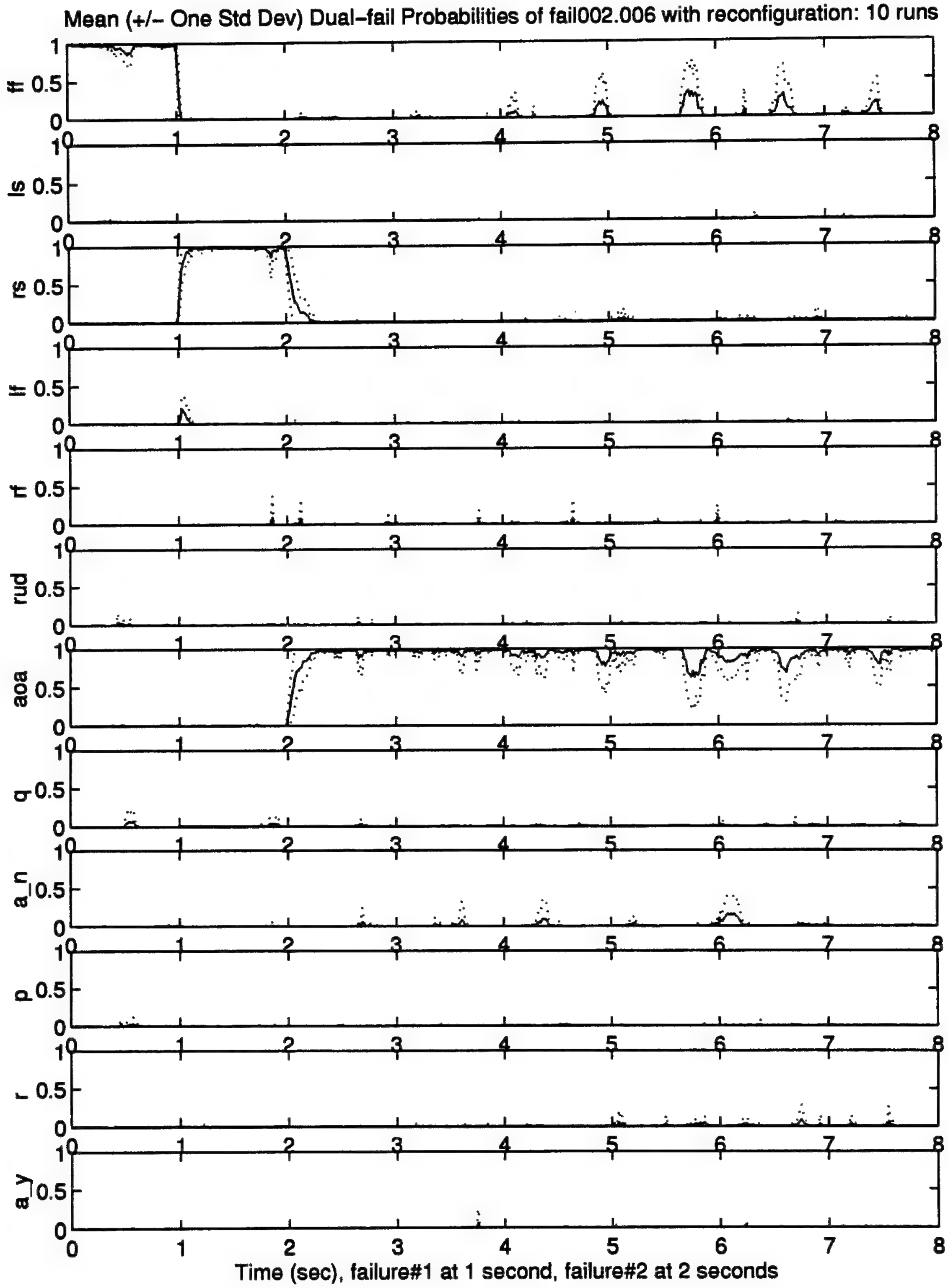
Mean (+/- One Std Dev) Dual-fail Probabilities of fail02.01 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

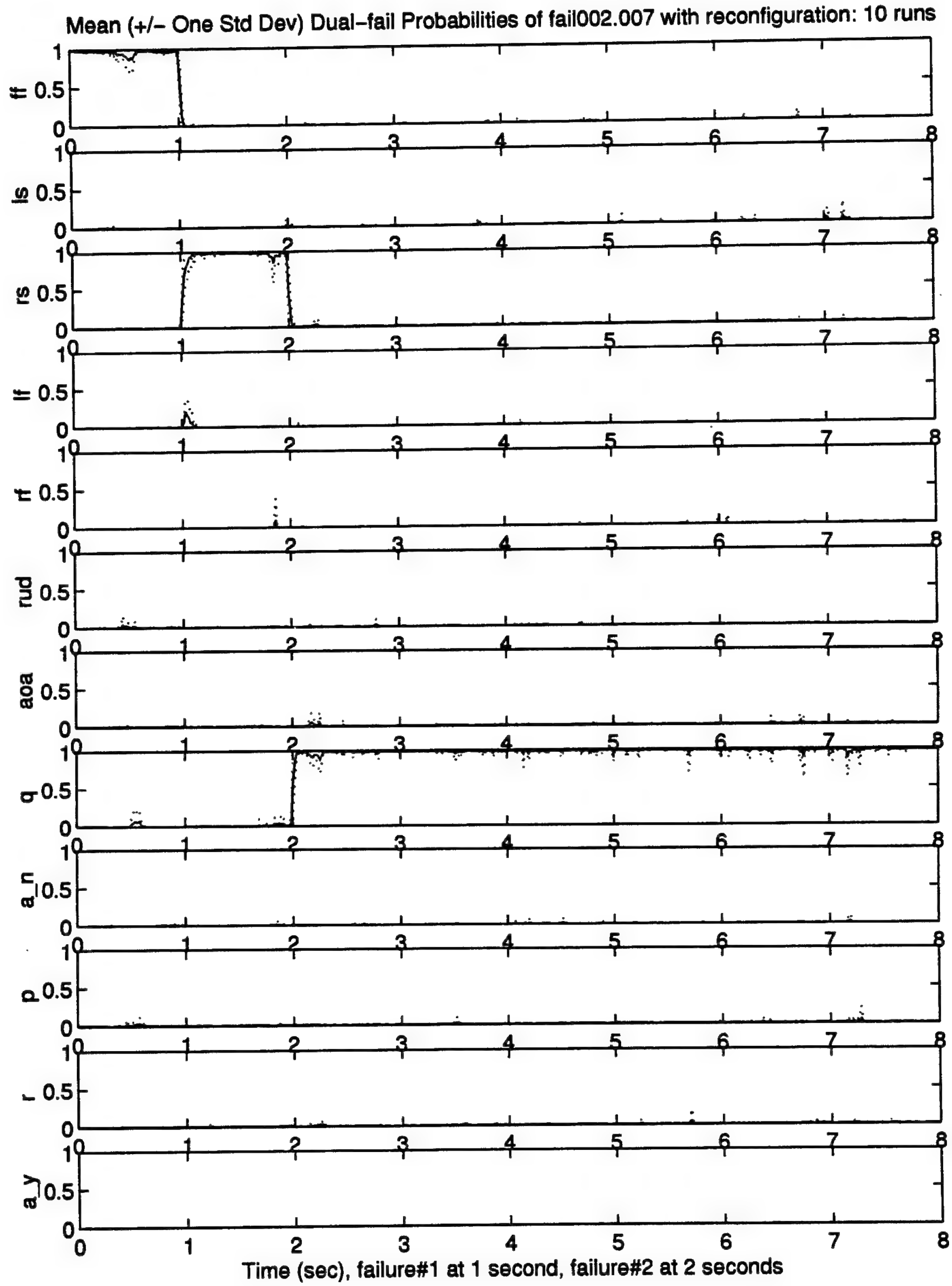


Mean (+/- One Std Dev) Dual-fail Probabilities of fail02.03 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

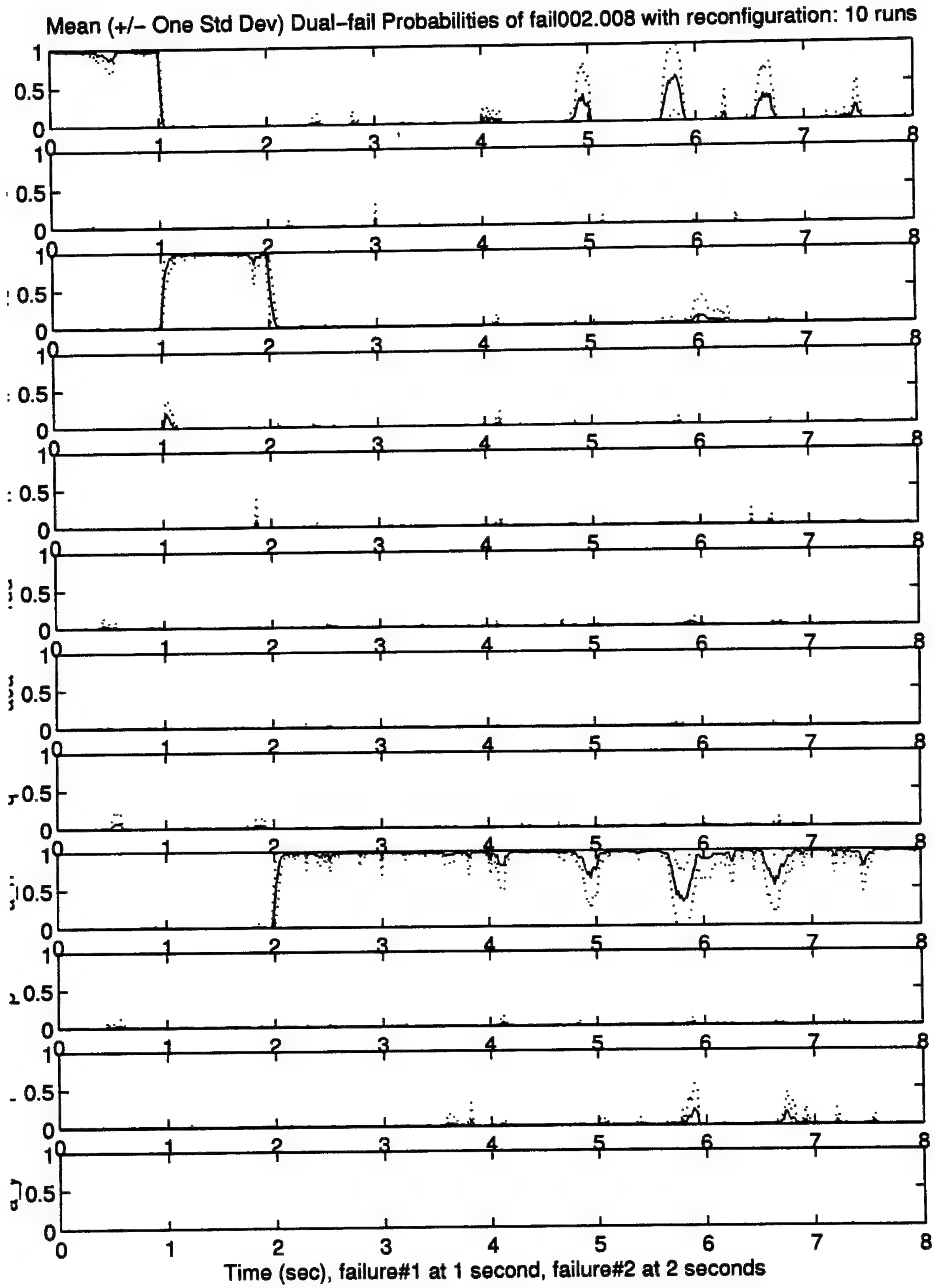

Mean (+/- One Std Dev) Dual-fail Probabilities of fail02.04 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

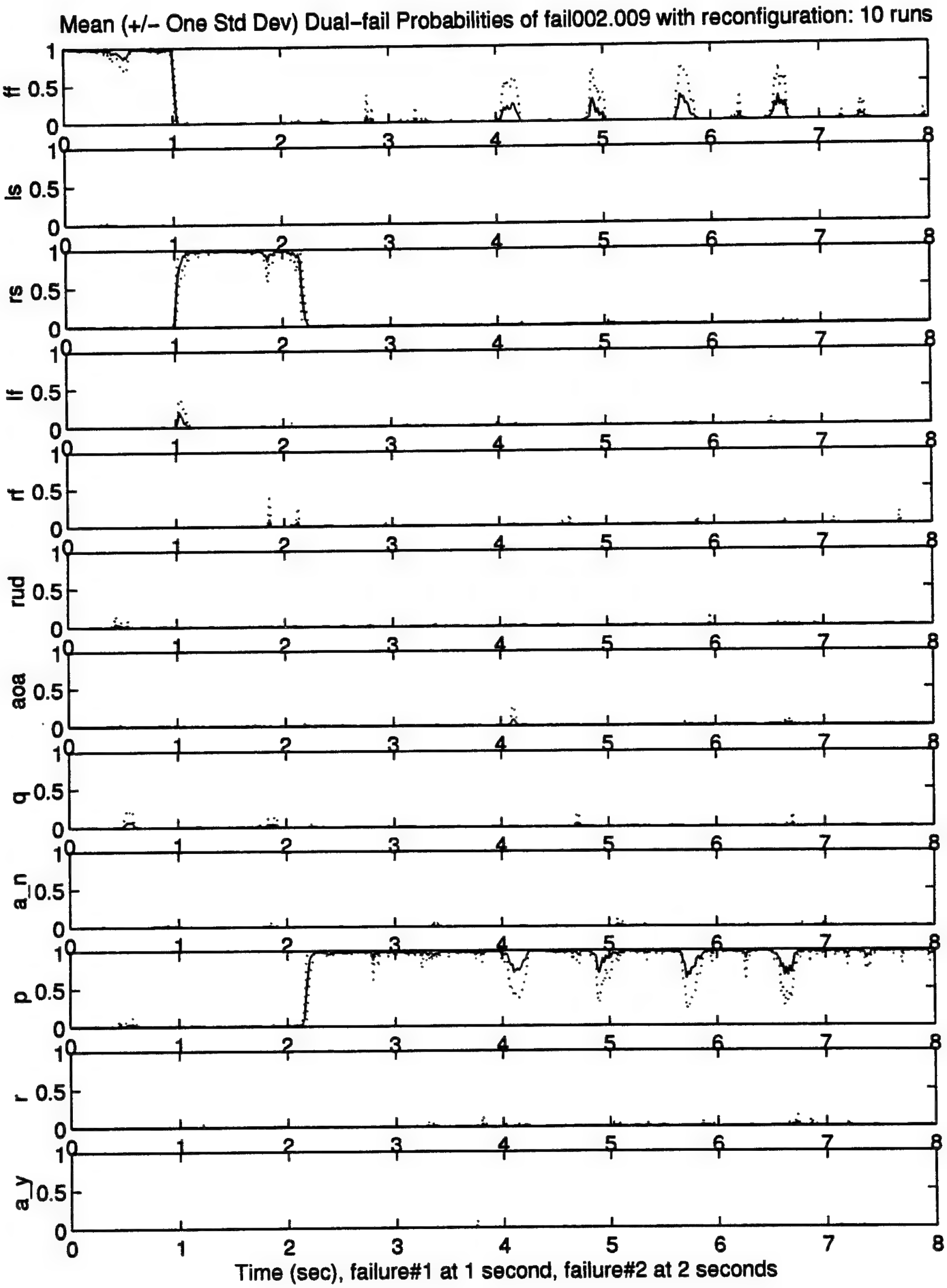

Mean (+/- One Std Dev) Dual-fail Probabilities of fail02.05 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

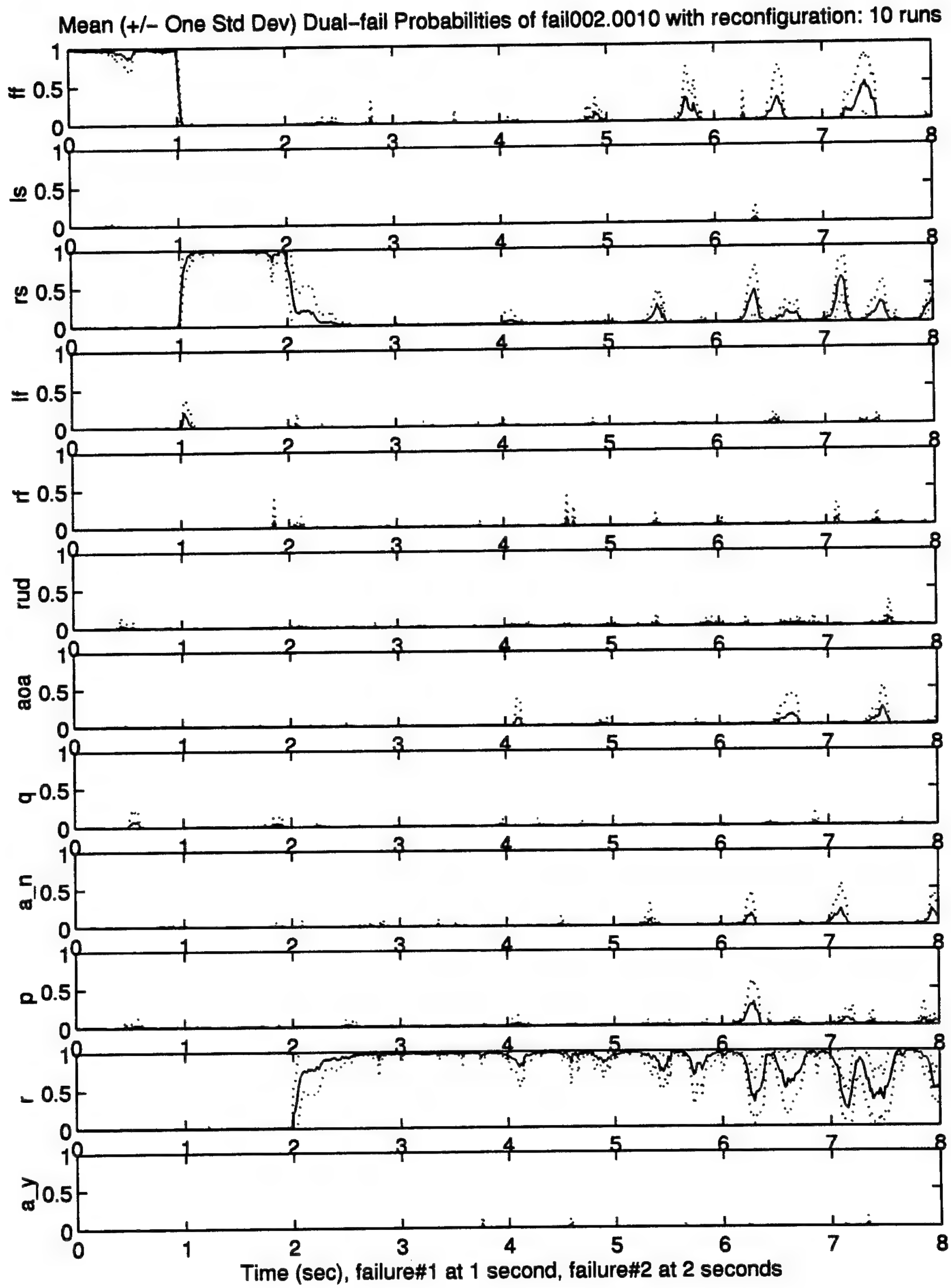

Mean (+/- One Std Dev) Dual-fail Probabilities of fail002.006 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

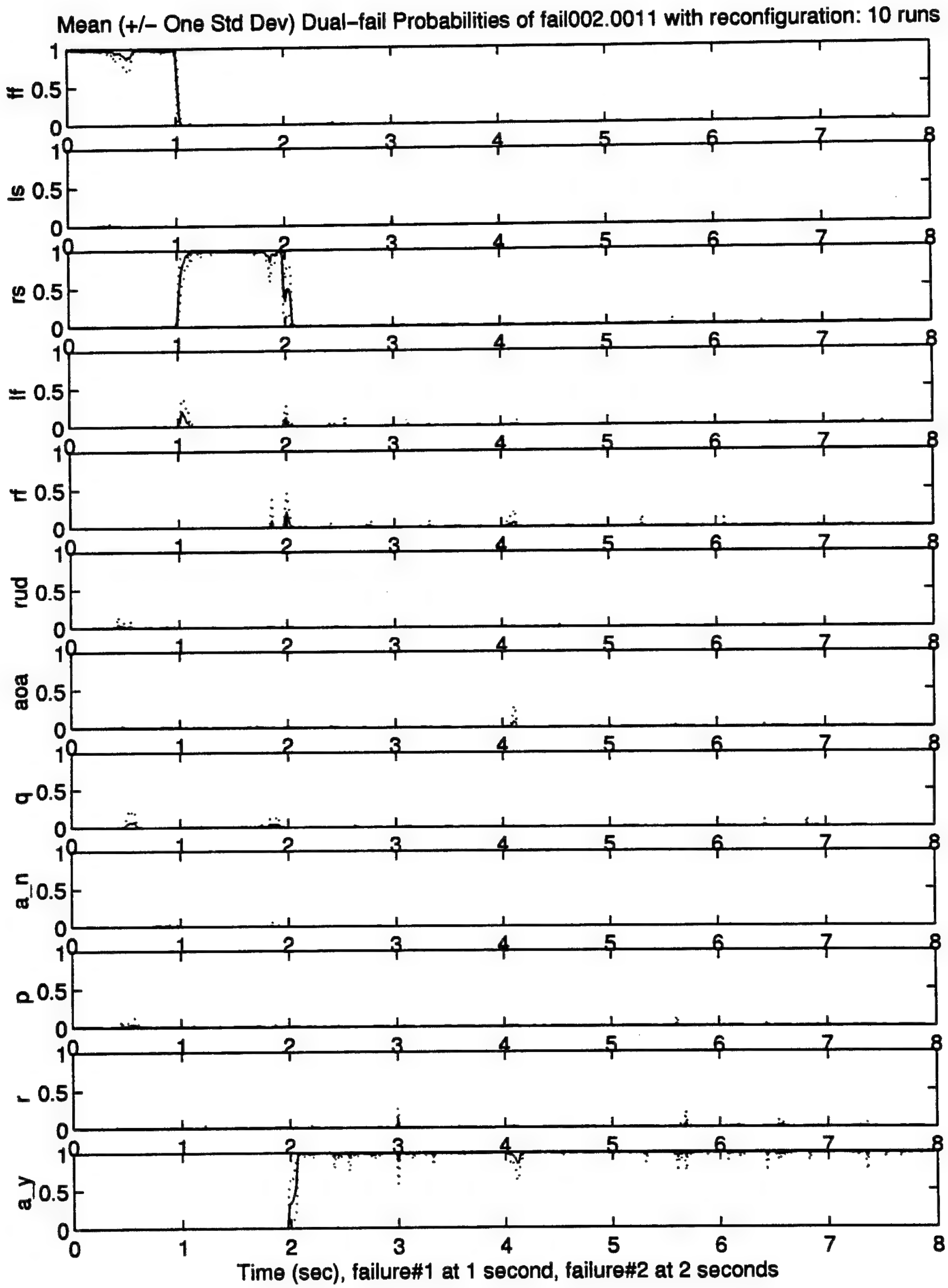


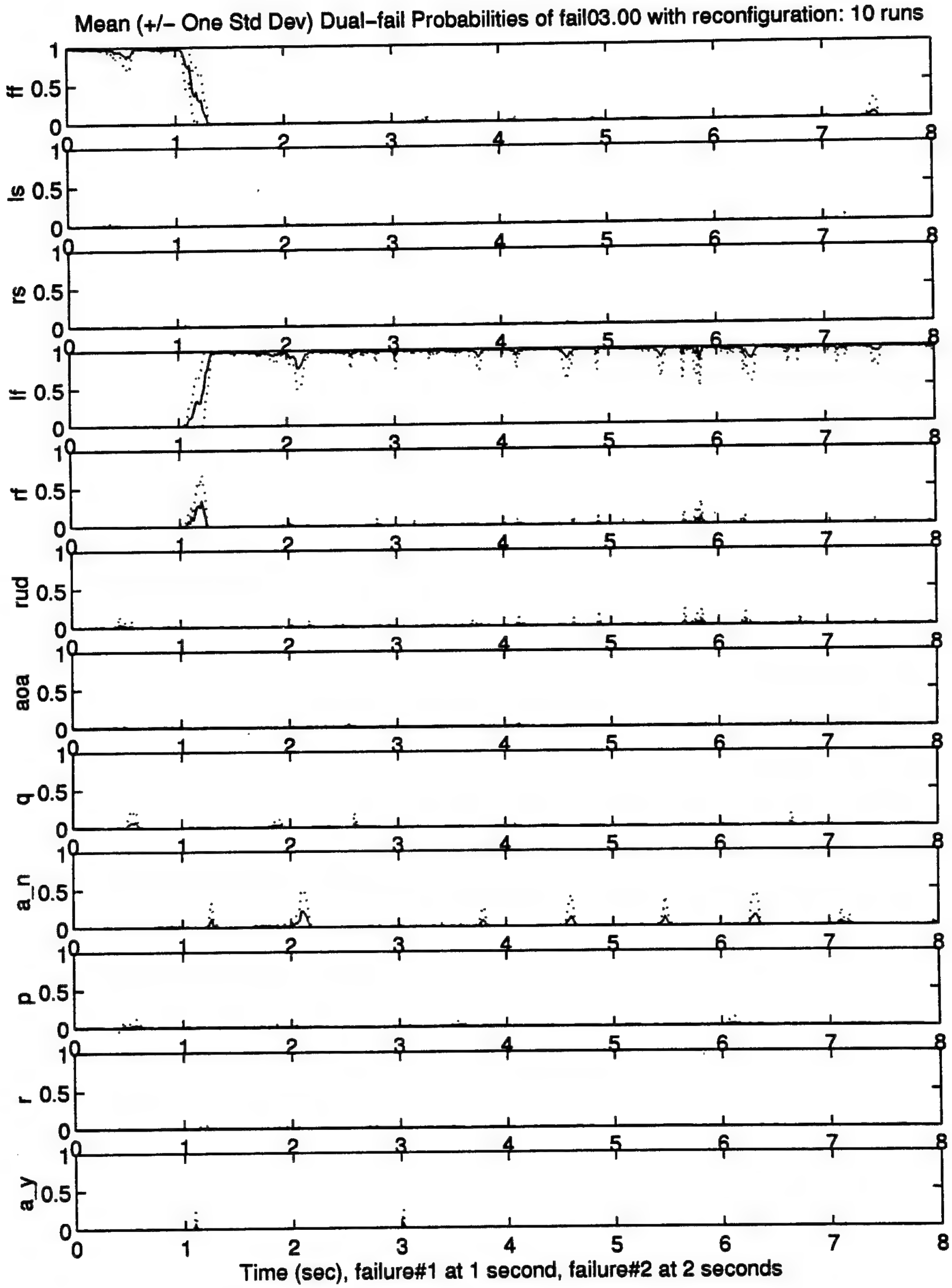
Mean (+/- One Std Dev) Dual-fail Probabilities of fail002.007 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

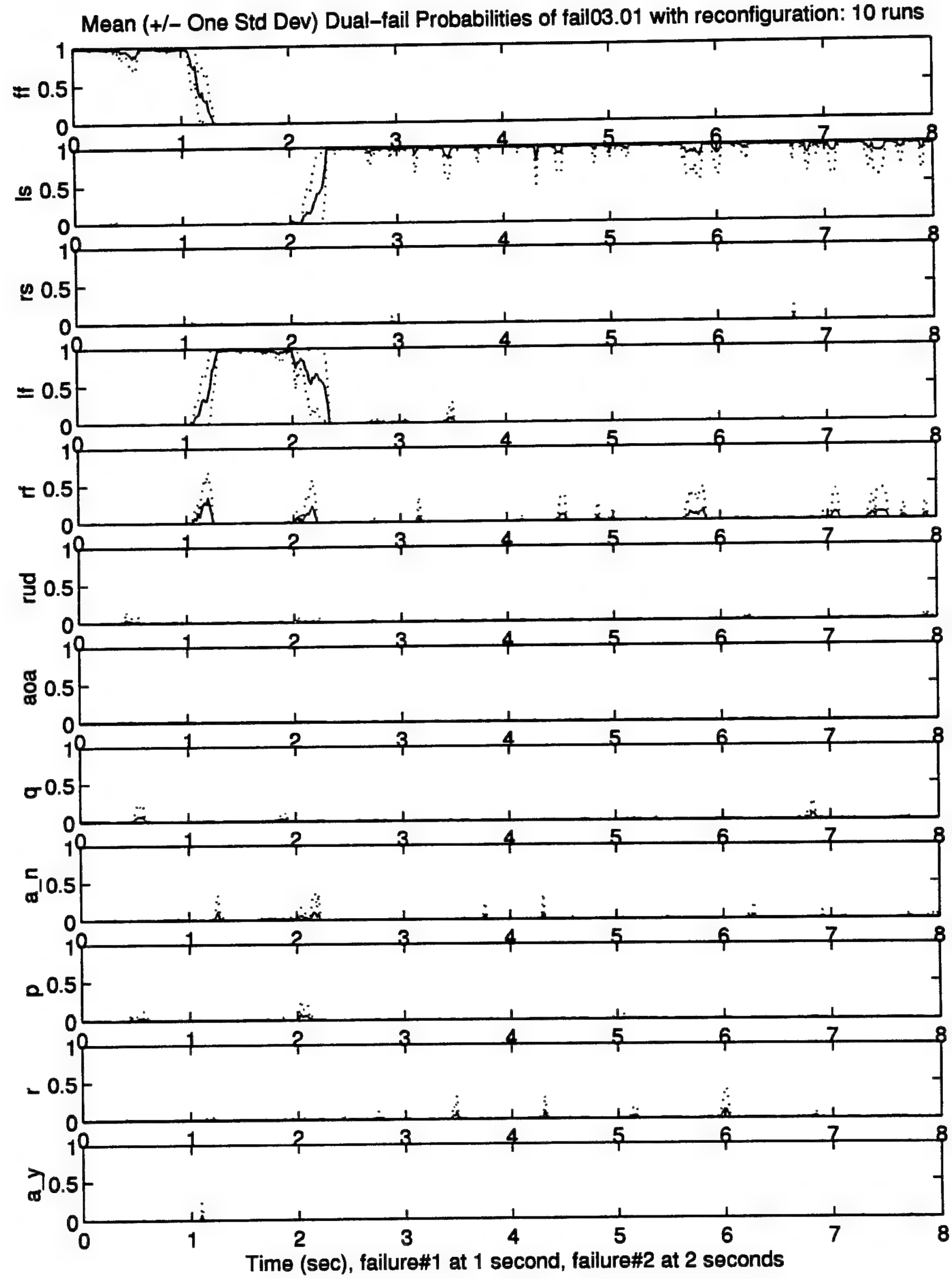

Mean (+/- One Std Dev) Dual-fail Probabilities of fail002.008 with reconfiguration: 10 runs
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

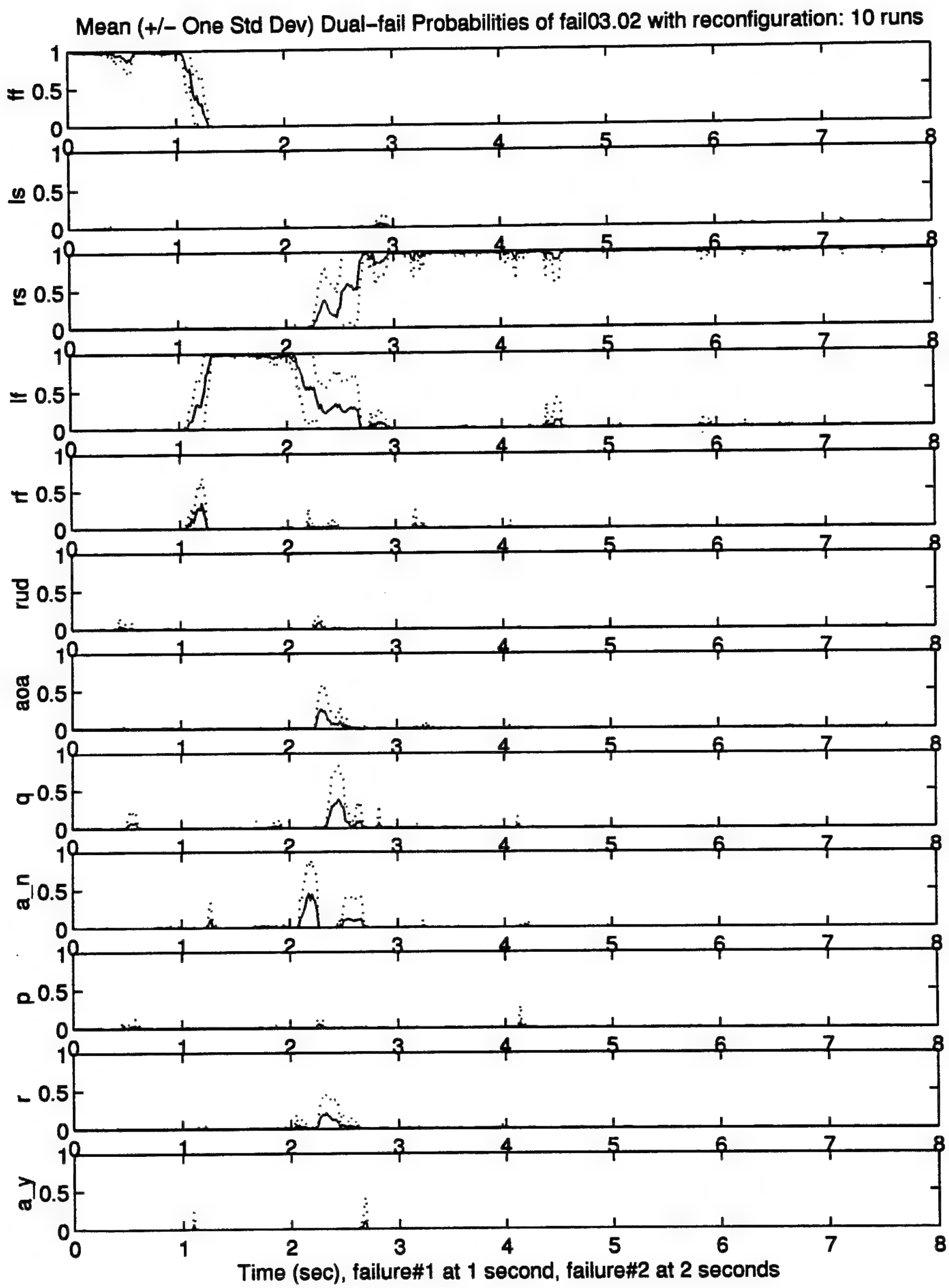

Mean (+/- One Std Dev) Dual-fail Probabilities of fail002.009 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

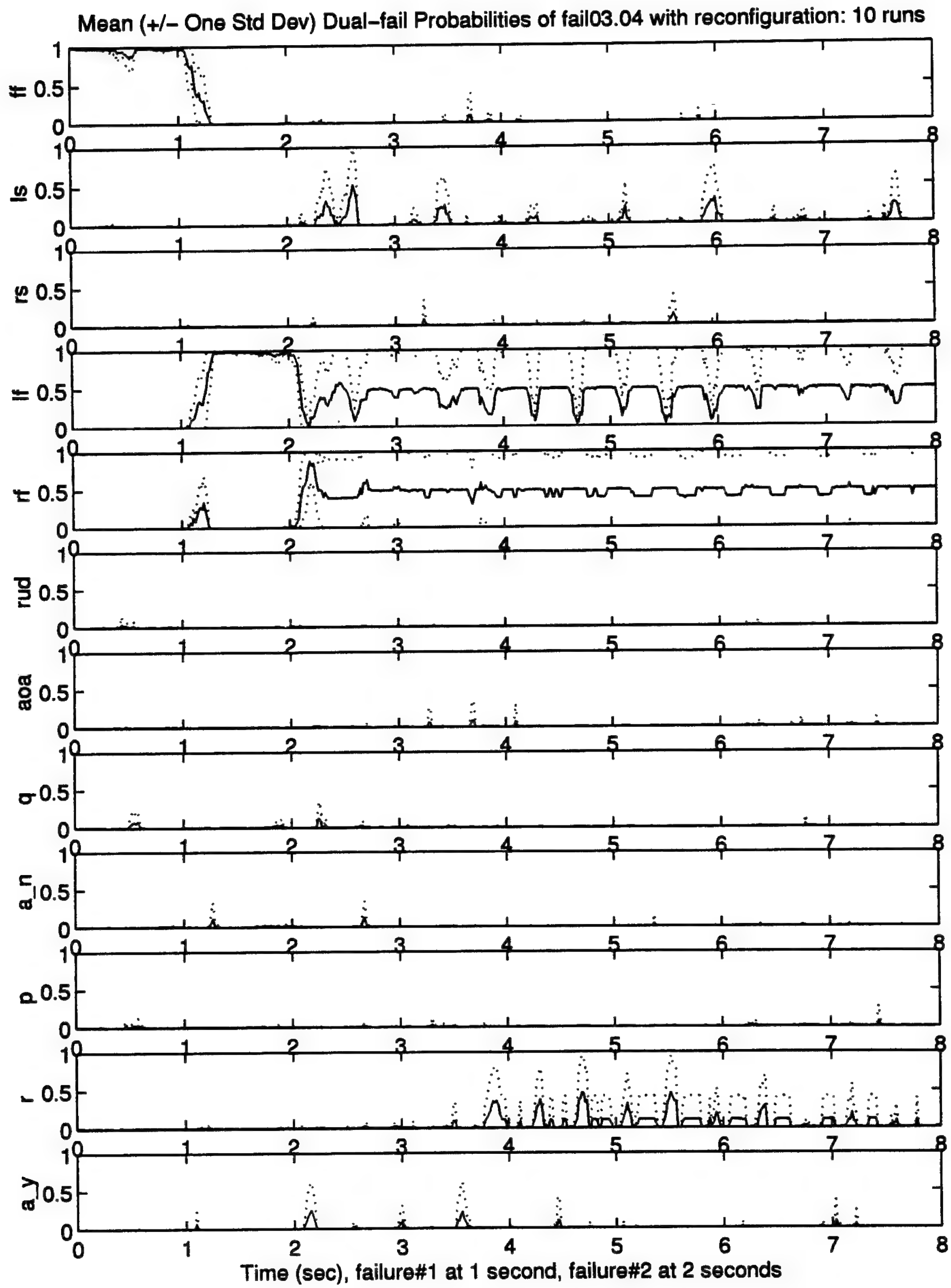

Mean (+/- One Std Dev) Dual-fail Probabilities of fail002.0010 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail002.0011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

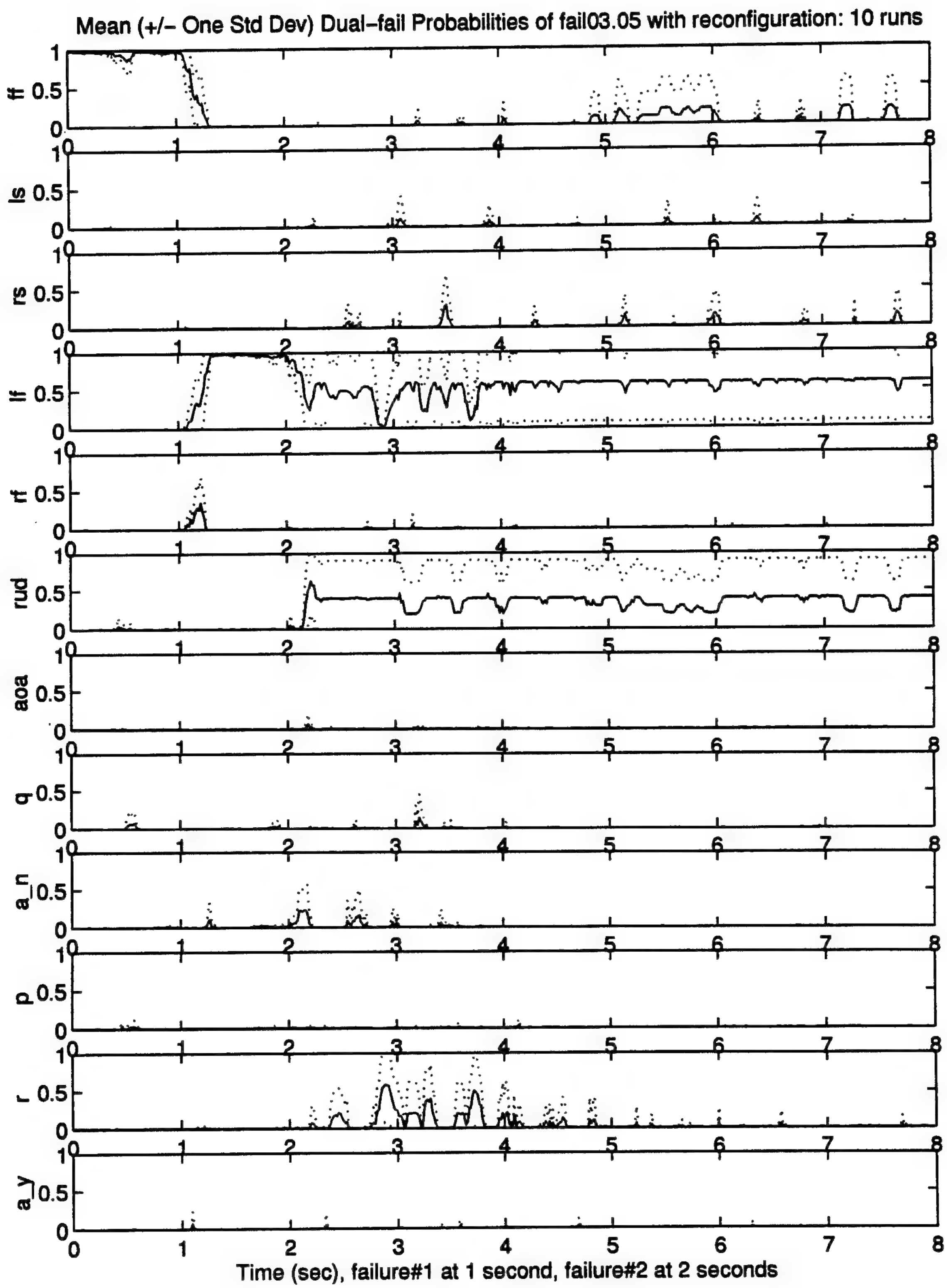

Mean (+/- One Std Dev) Dual-fail Probabilities of fail03.00 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

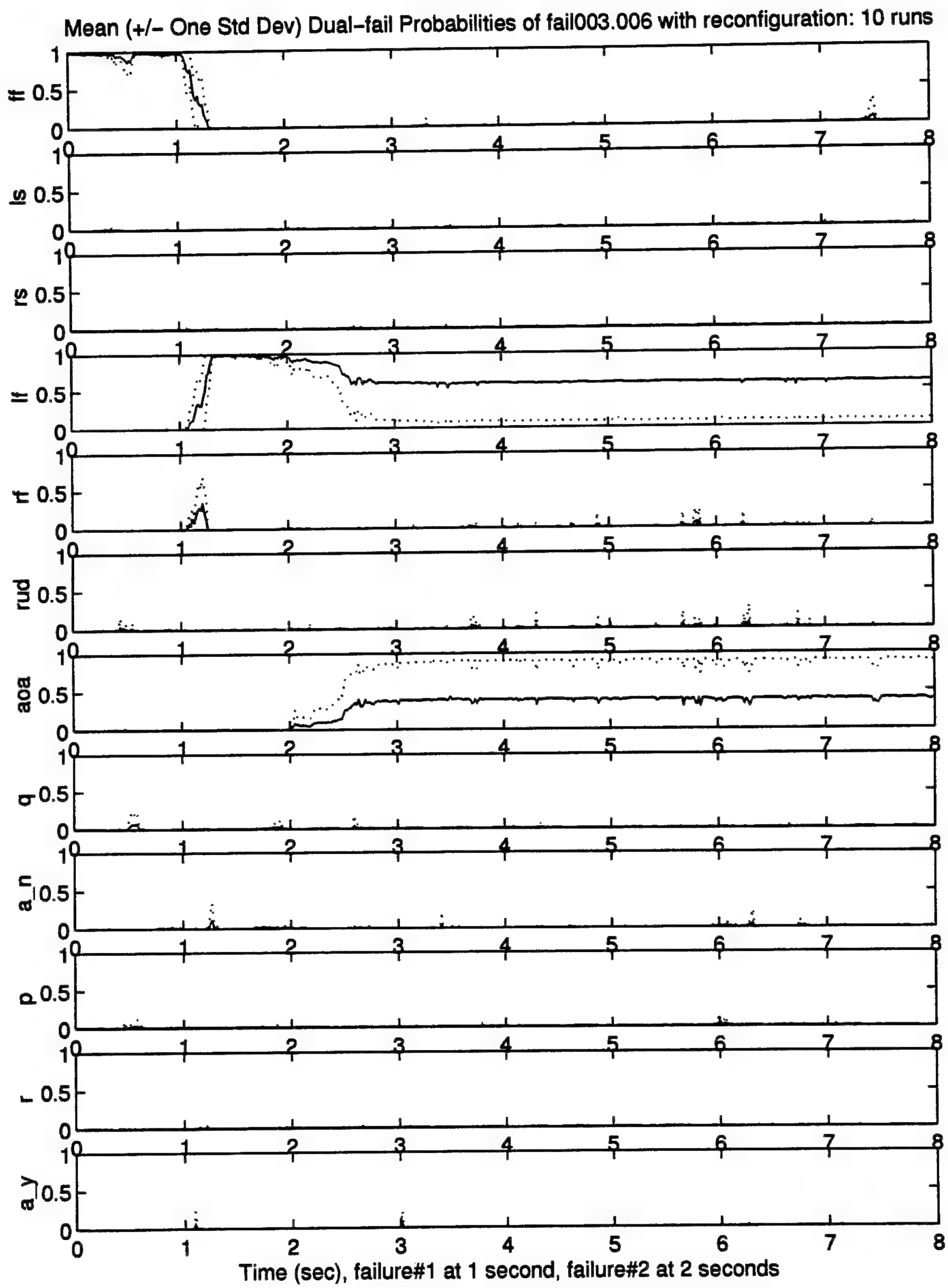

Mean (+/- One Std Dev) Dual-fail Probabilities of fail03.01 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail03.02 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

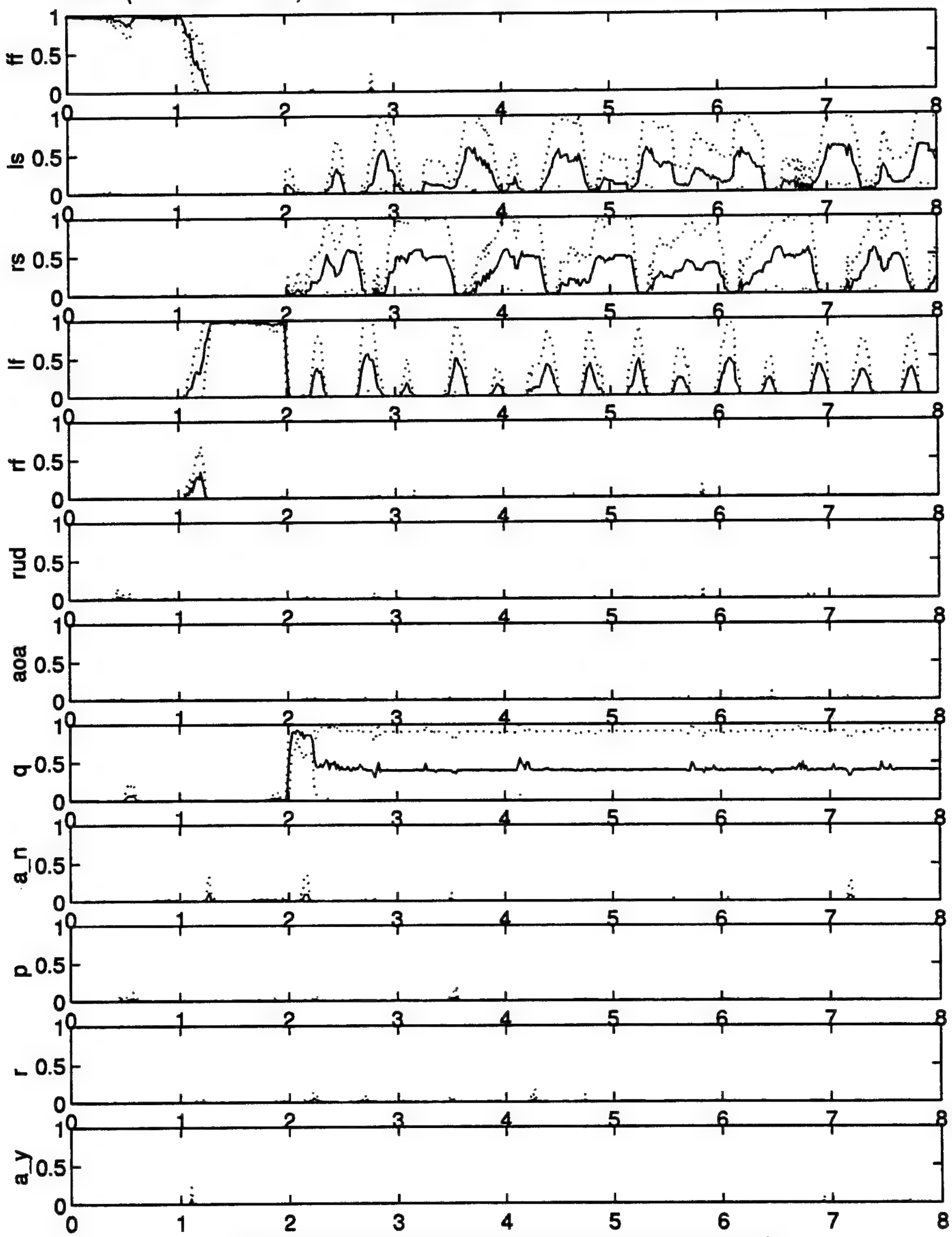


Mean (+/- One Std Dev) Dual-fail Probabilities of fail03.04 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

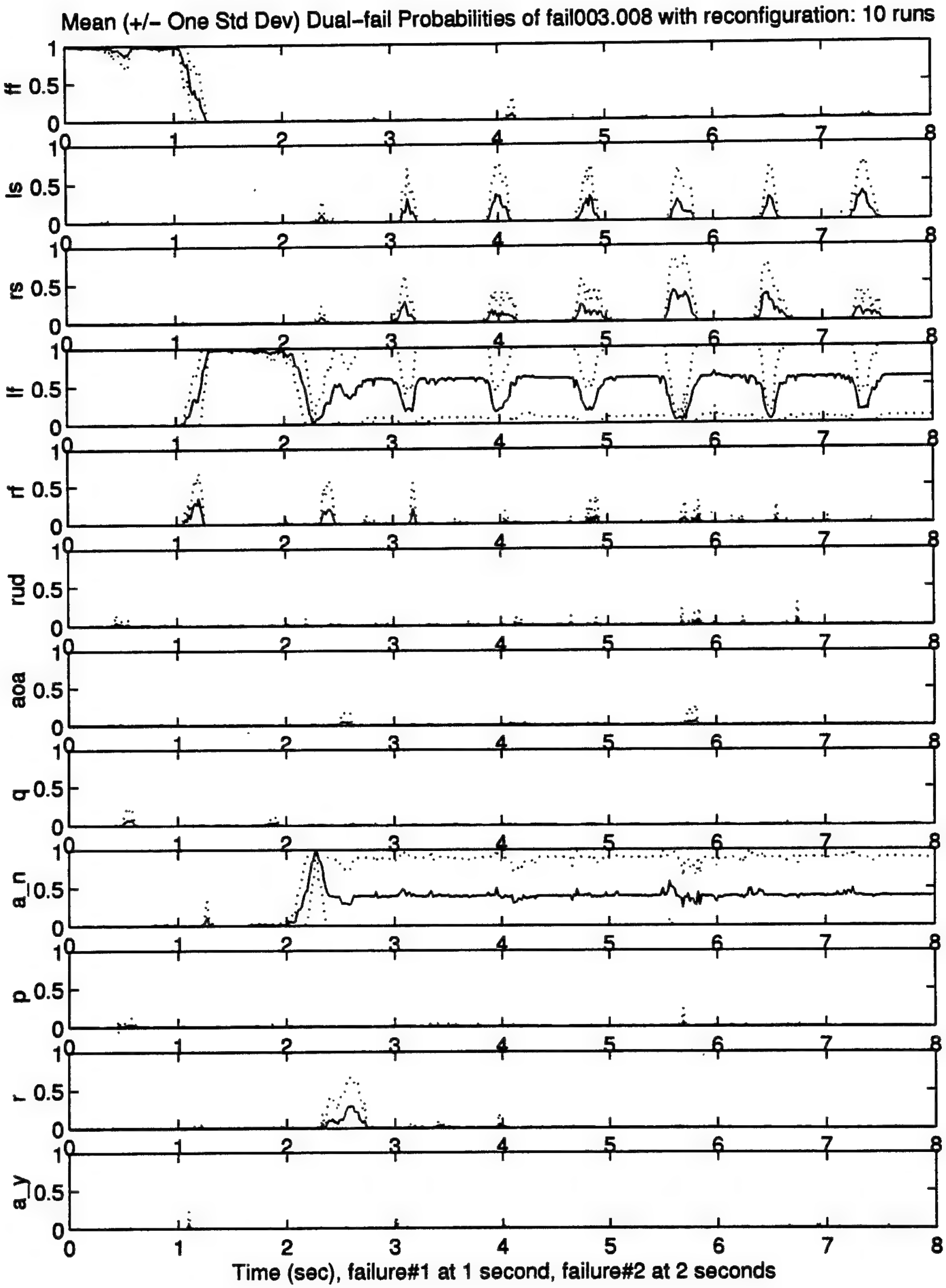

Mean (+/- One Std Dev) Dual-fail Probabilities of fail03.05 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail003.006 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

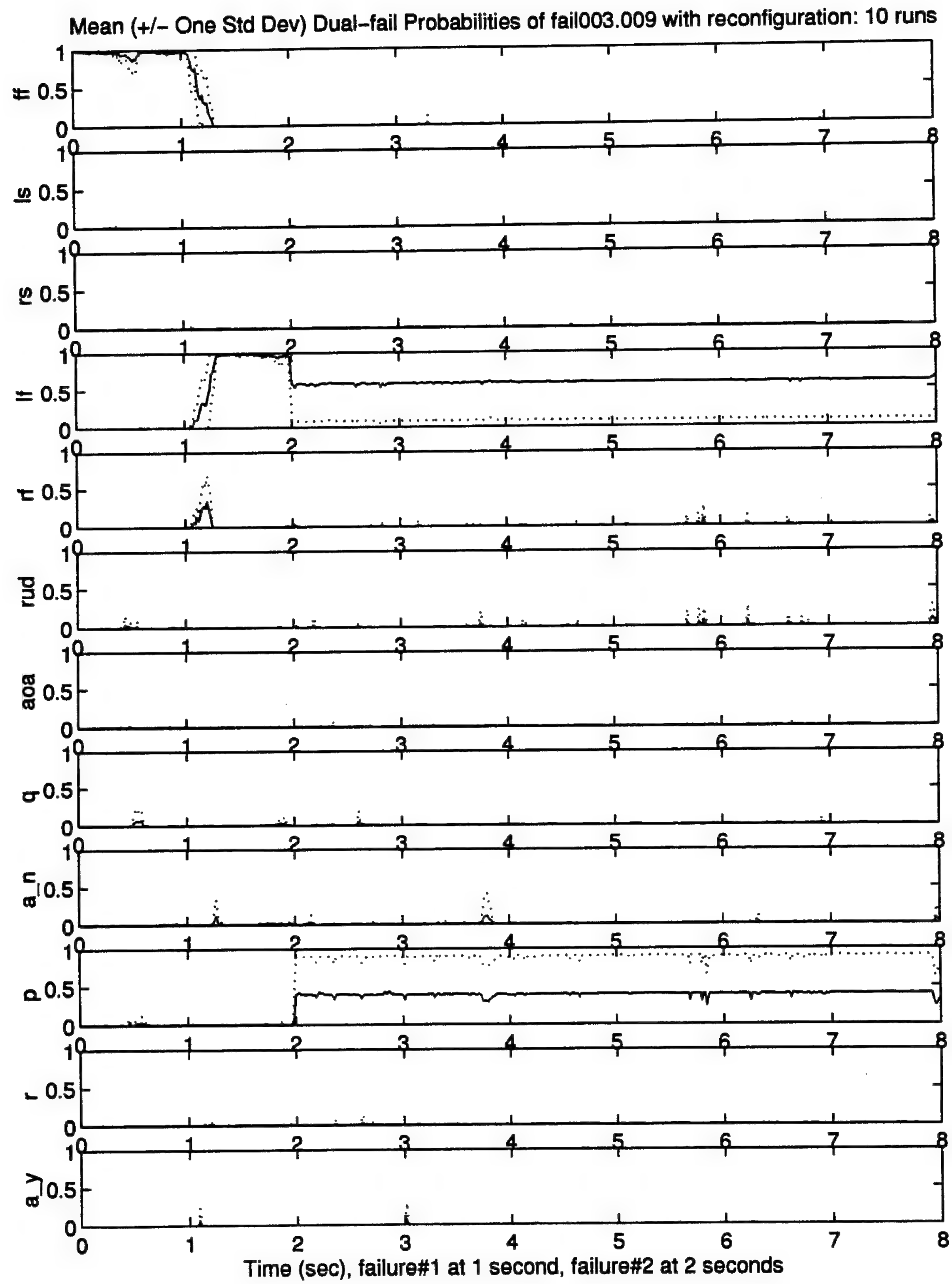
Mean (+/- One Std Dev) Dual-fail Probabilities of fail003.007 with reconfiguration: 10 runs



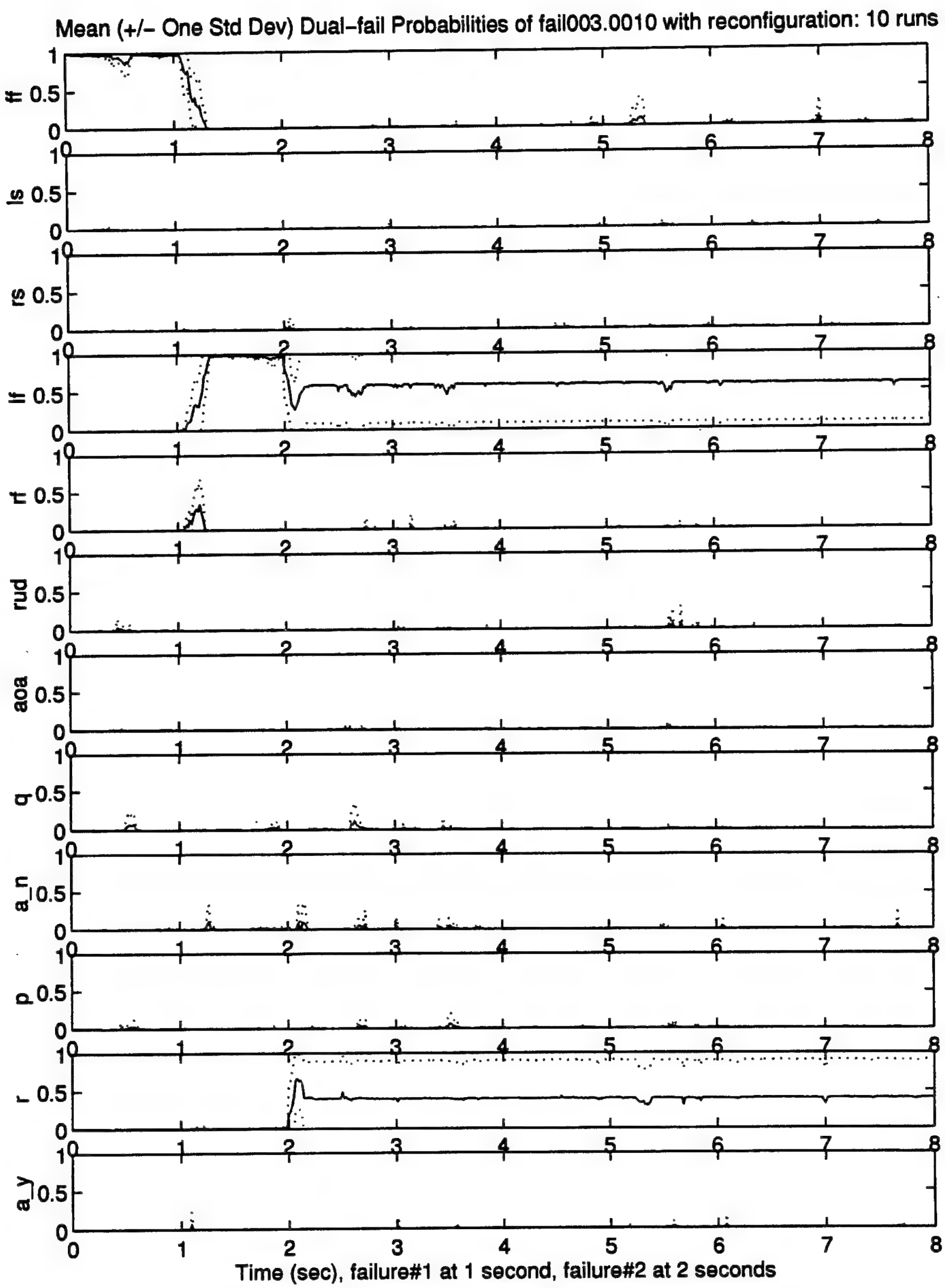
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



Mean (+/- One Std Dev) Dual-fail Probabilities of fail003.008 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

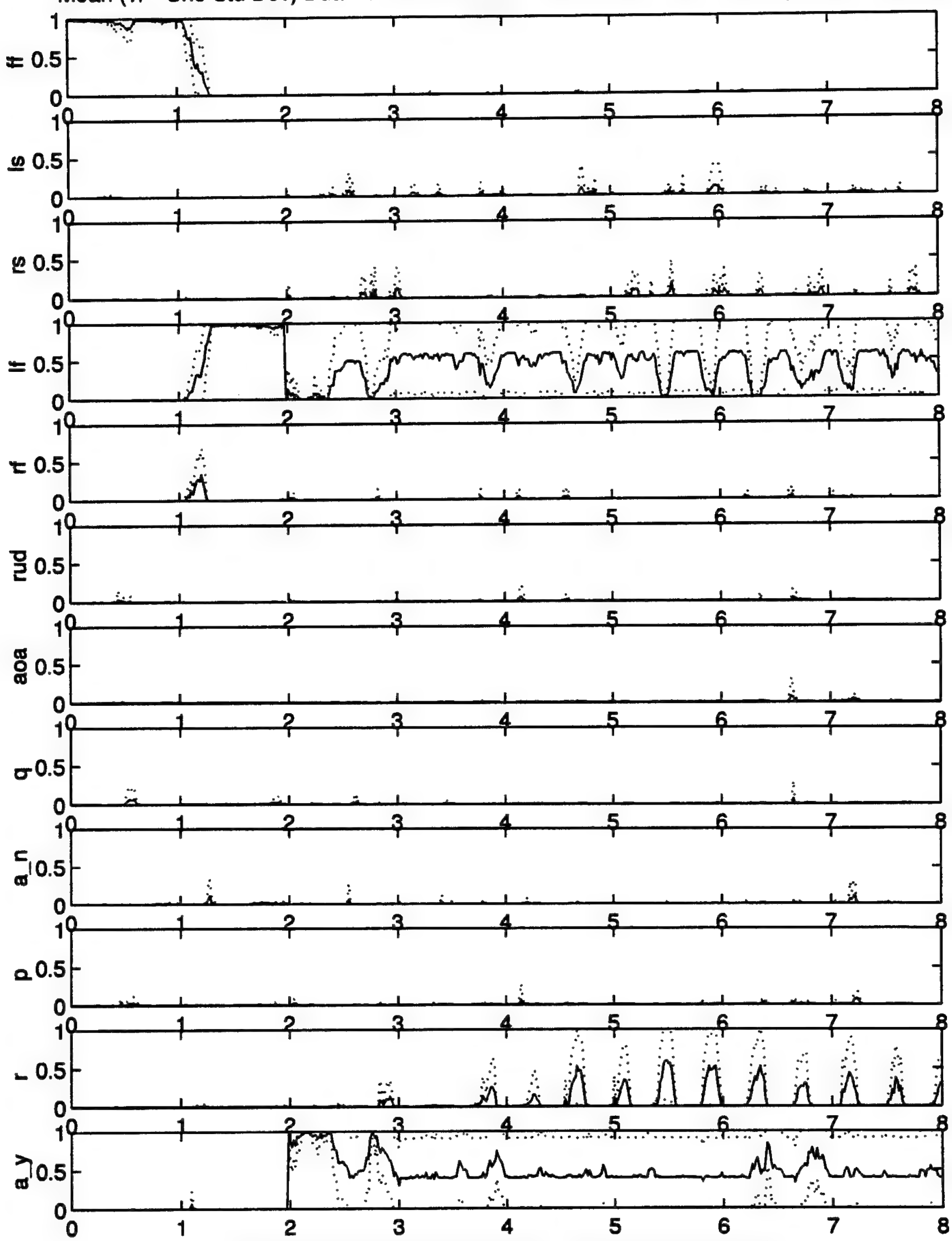


Mean (+/- One Std Dev) Dual-fail Probabilities of fail003.009 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

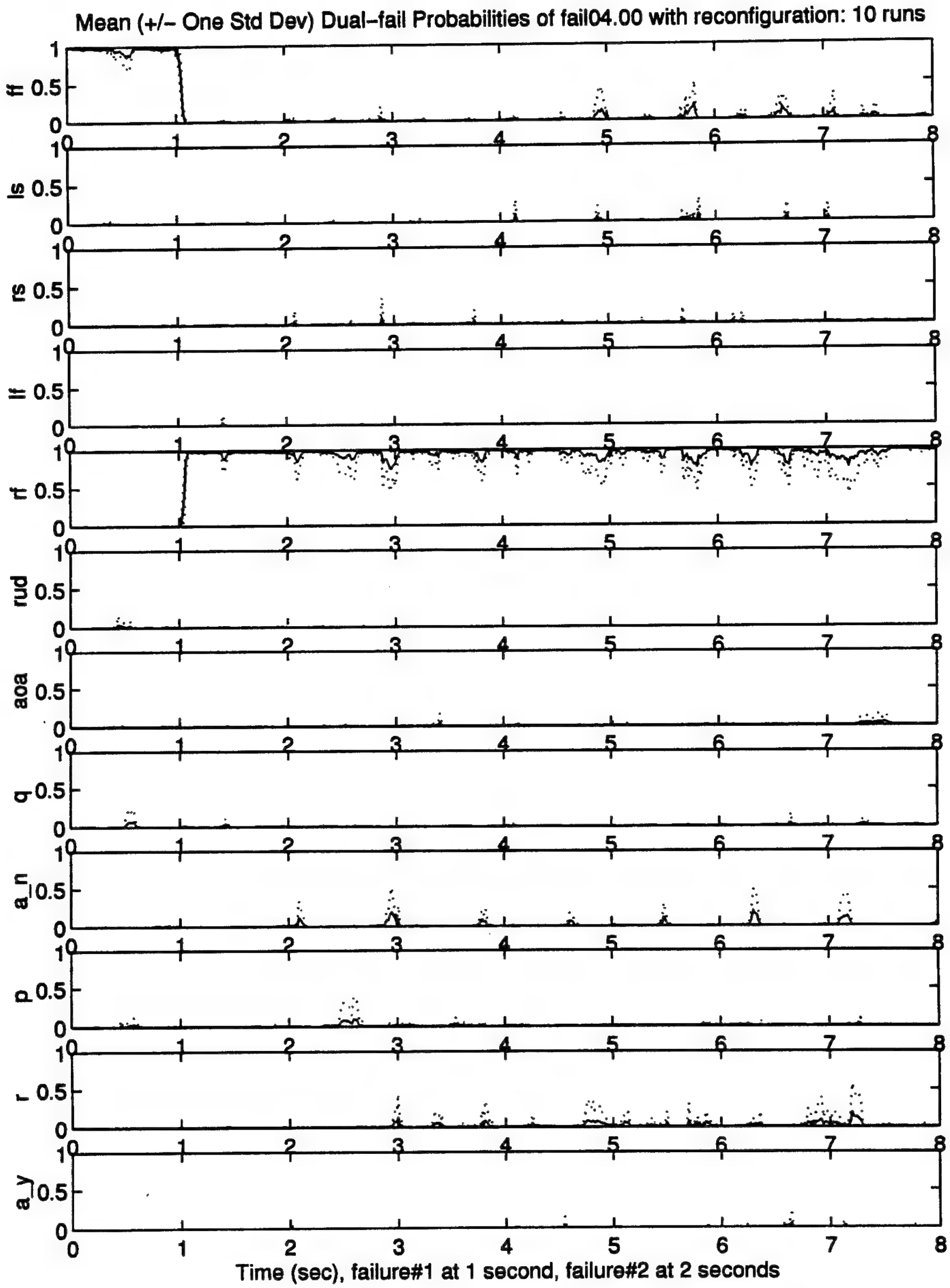


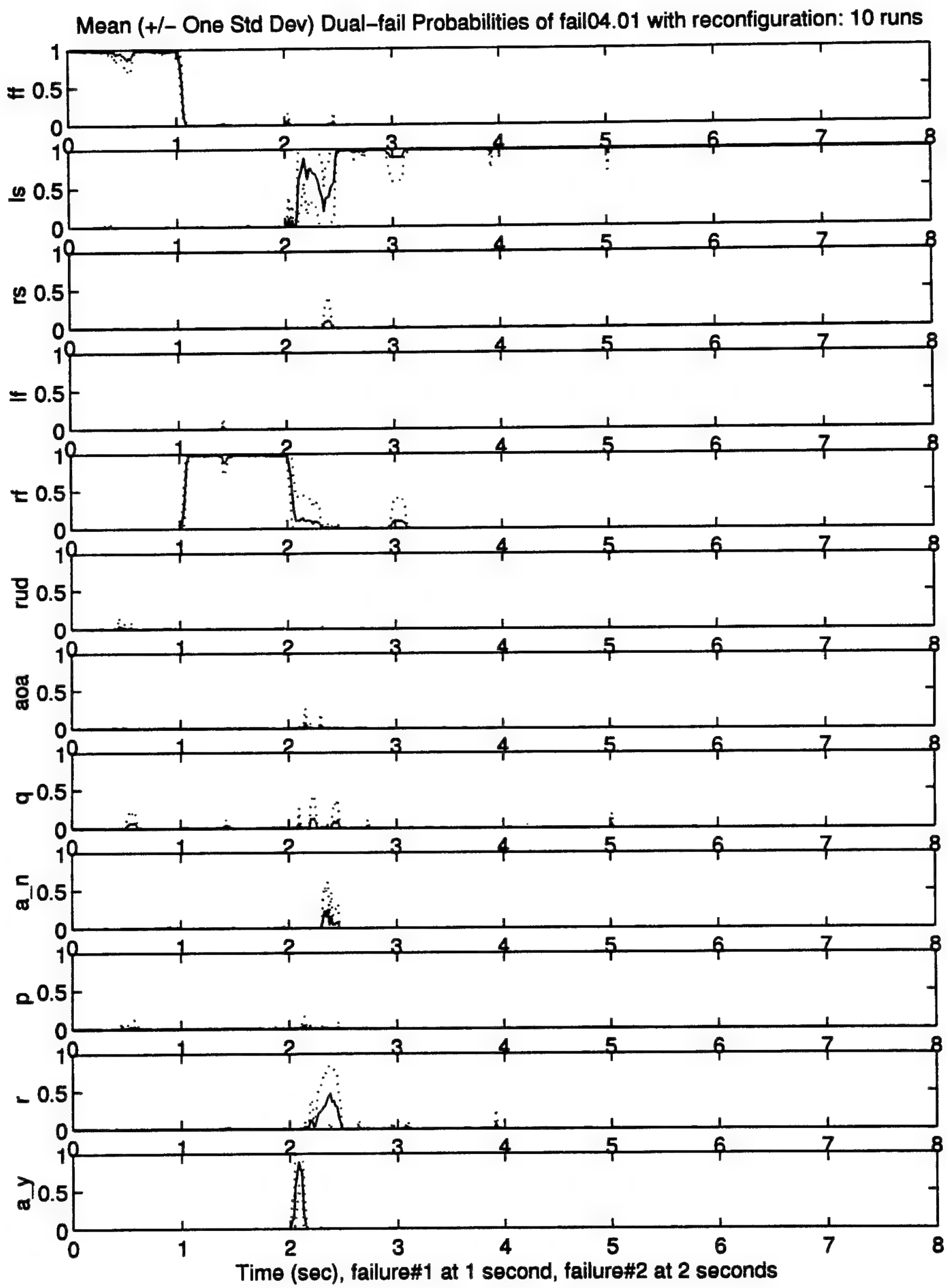
Mean (+/- One Std Dev) Dual-fail Probabilities of fail003.0010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

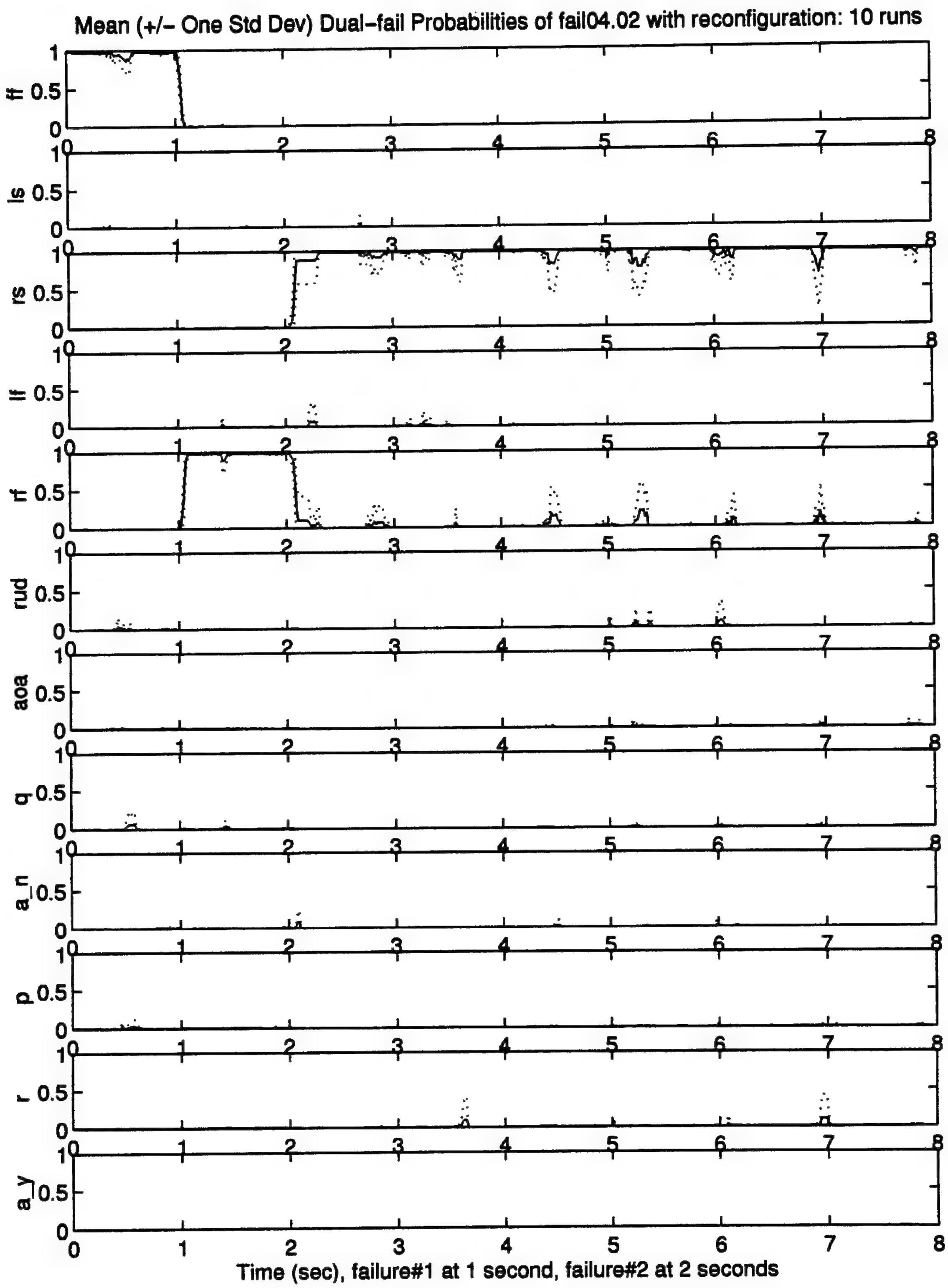
Mean (+/- One Std Dev) Dual-fail Probabilities of fail003.0011 with reconfiguration: 10 runs

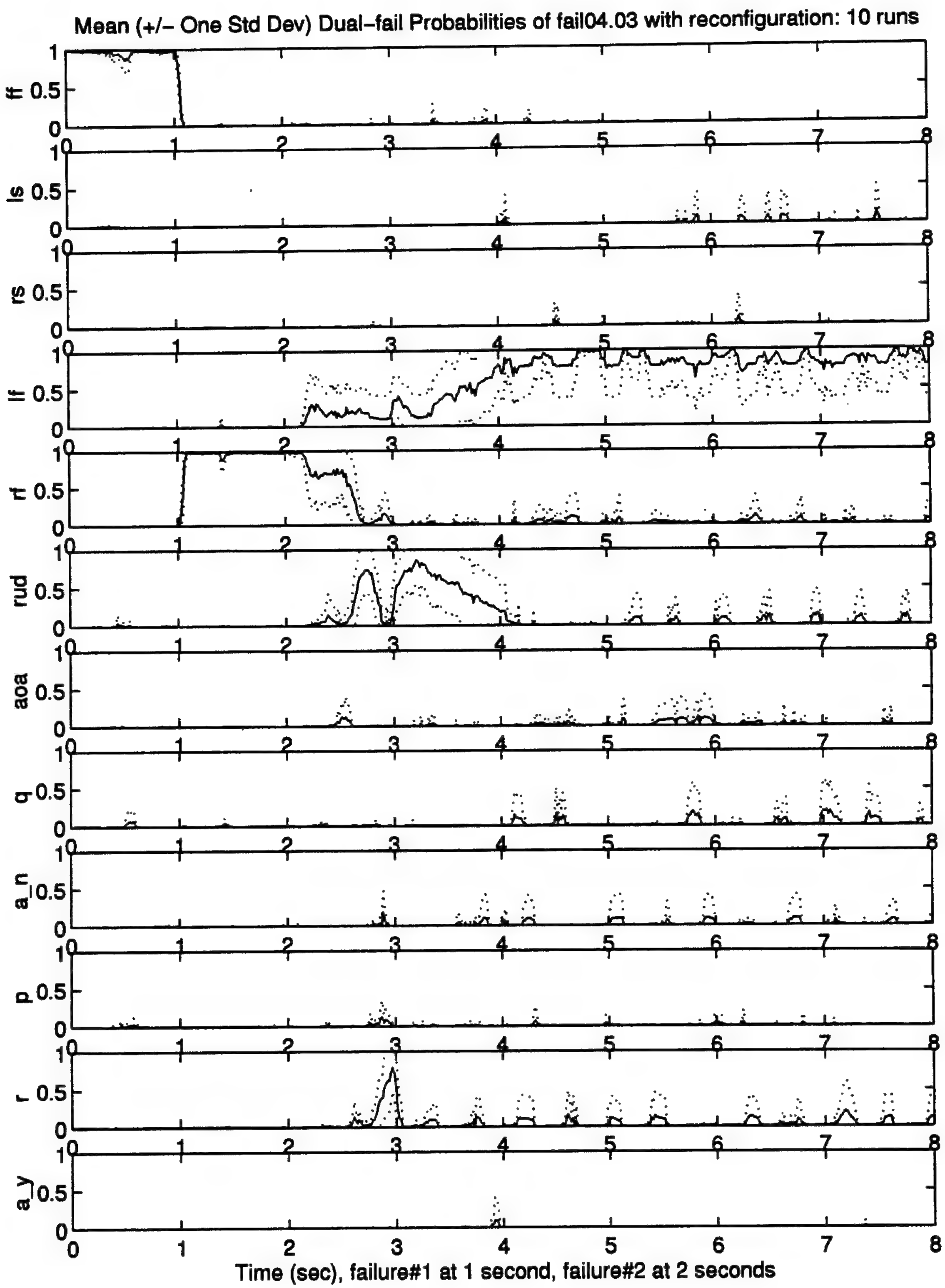


Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

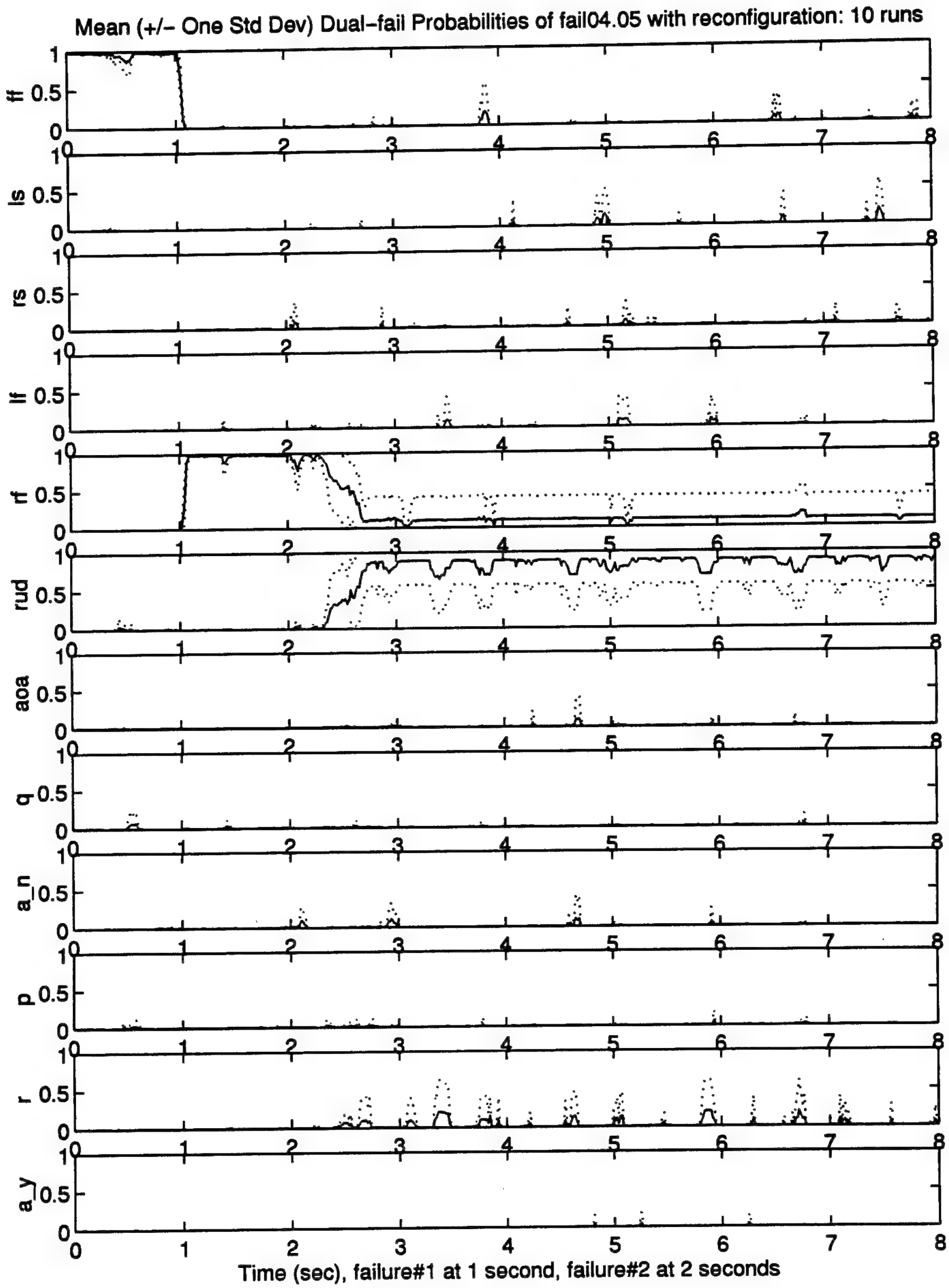

Mean (+/- One Std Dev) Dual-fail Probabilities of fail04.00 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail04.01 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

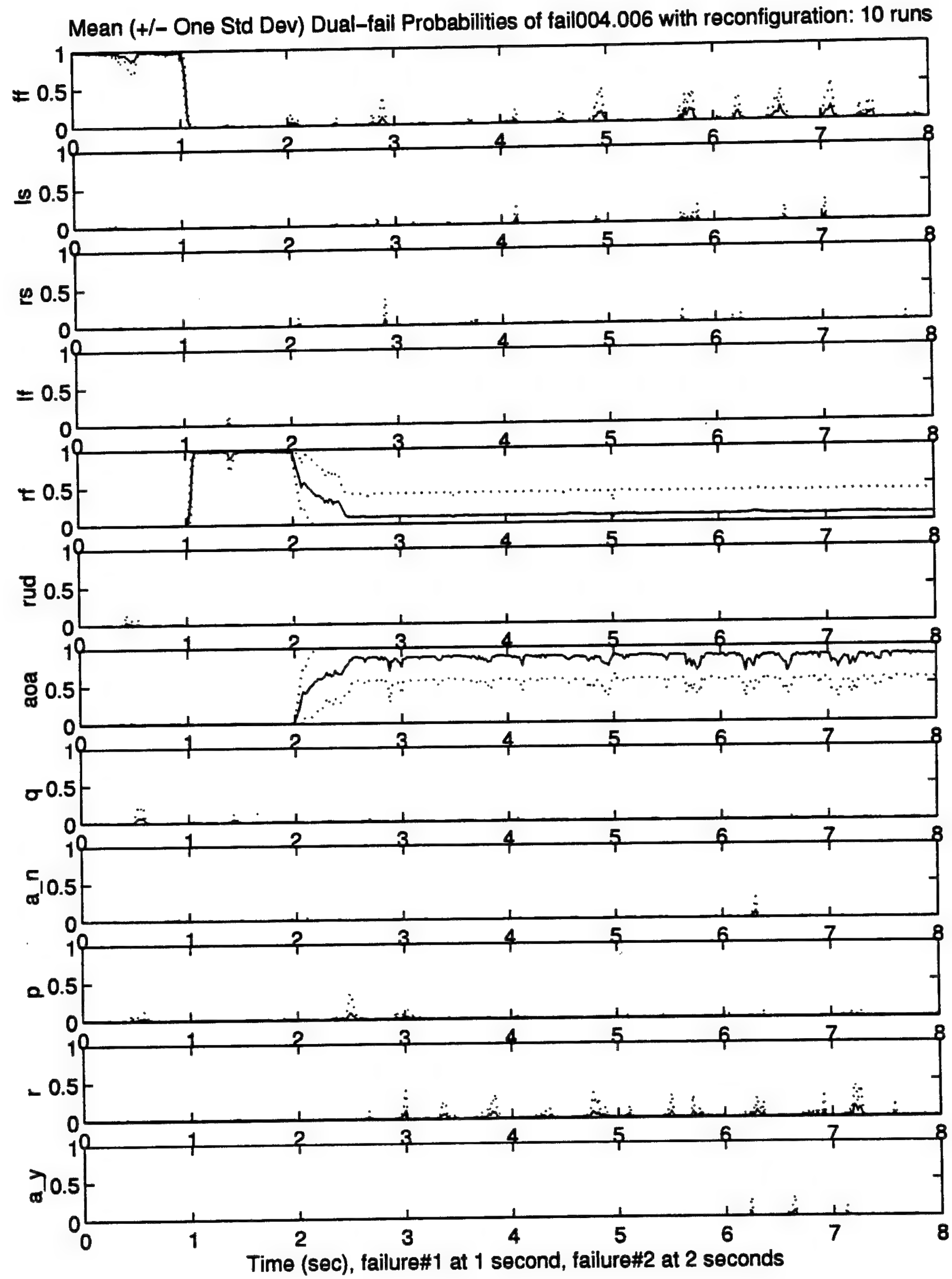

Mean (+/- One Std Dev) Dual-fail Probabilities of fail04.02 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

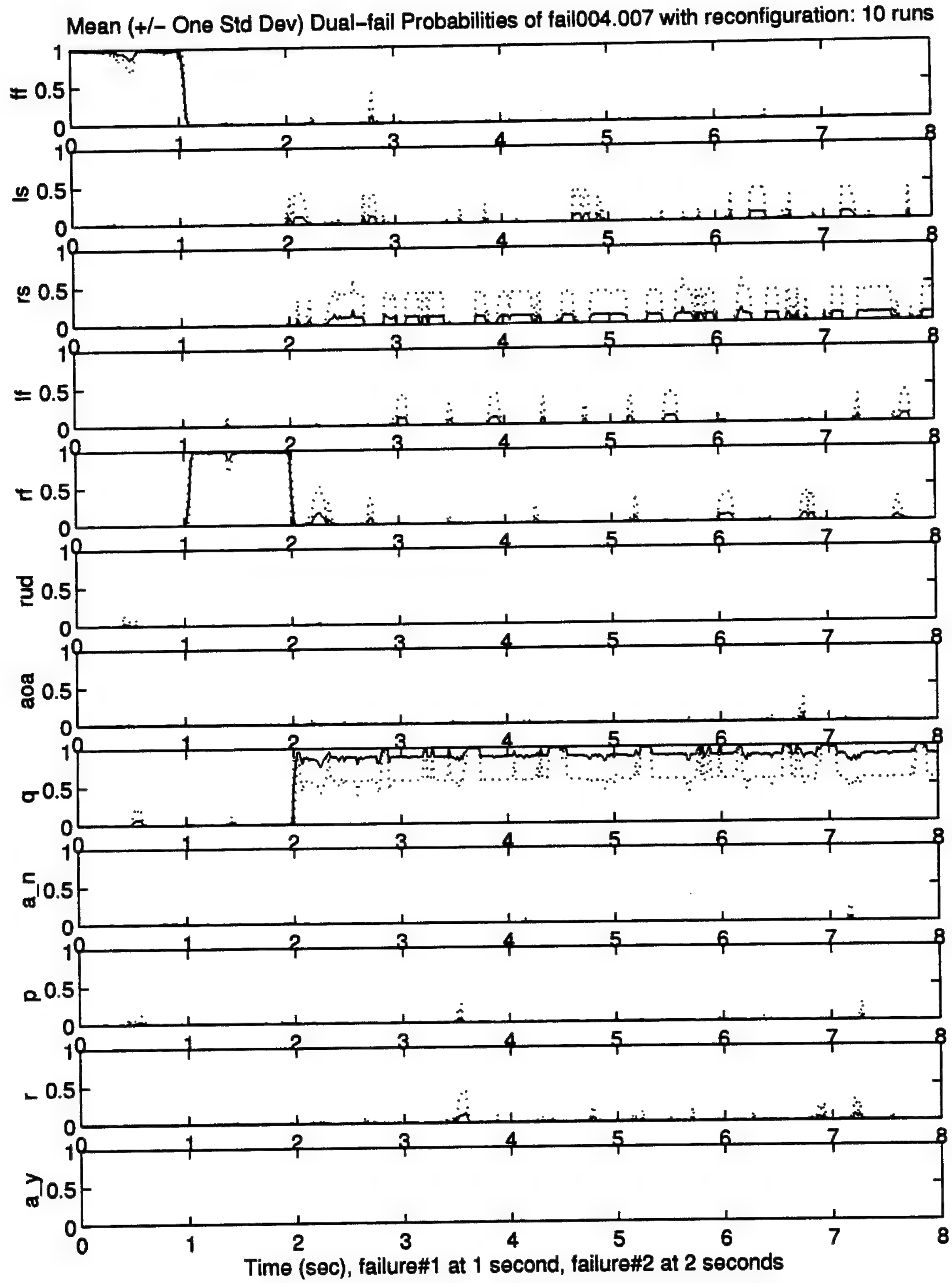


Mean (+/- One Std Dev) Dual-fail Probabilities of fail04.03 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

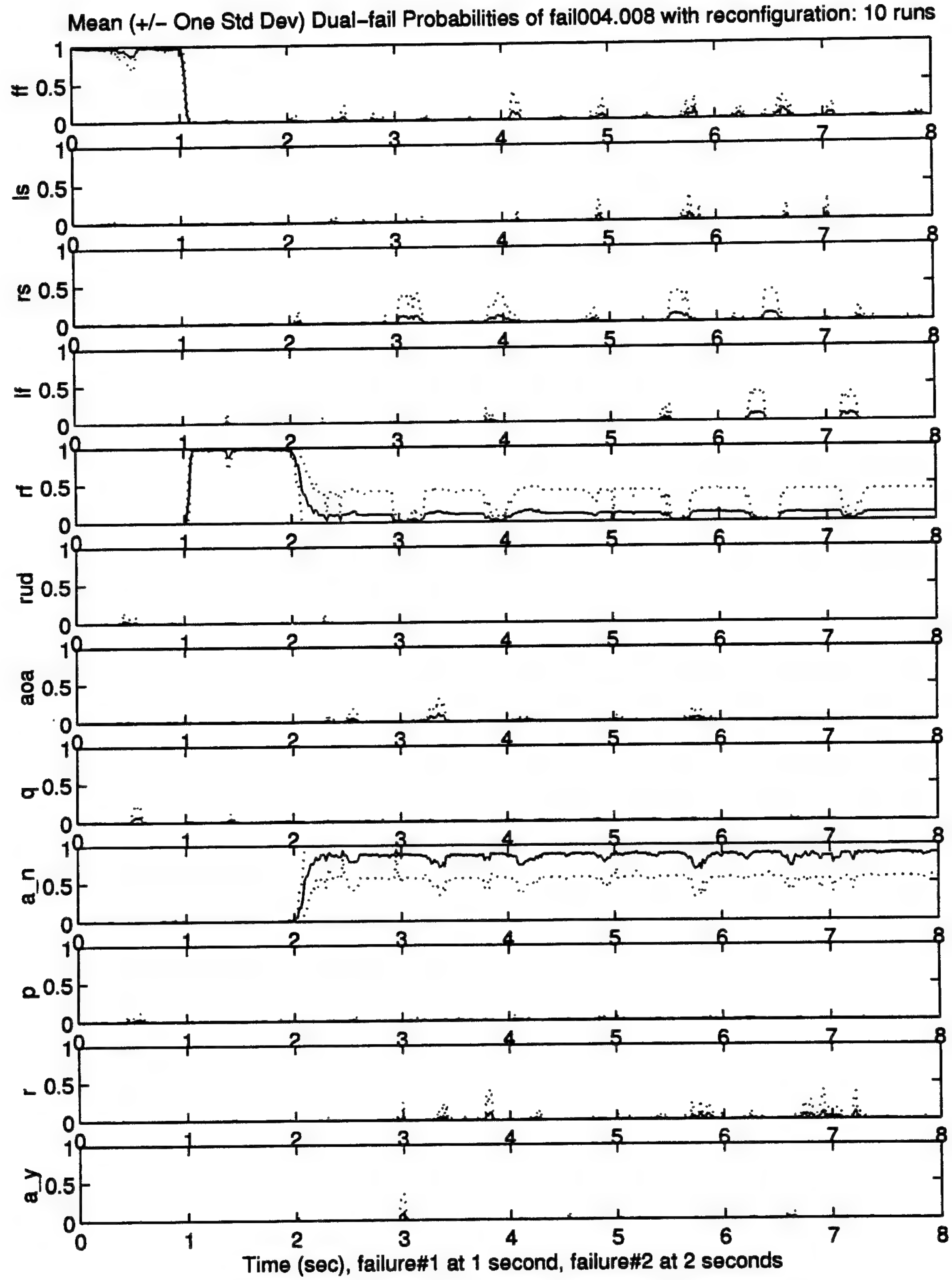


Mean (+/- One Std Dev) Dual-fail Probabilities of fail04.05 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

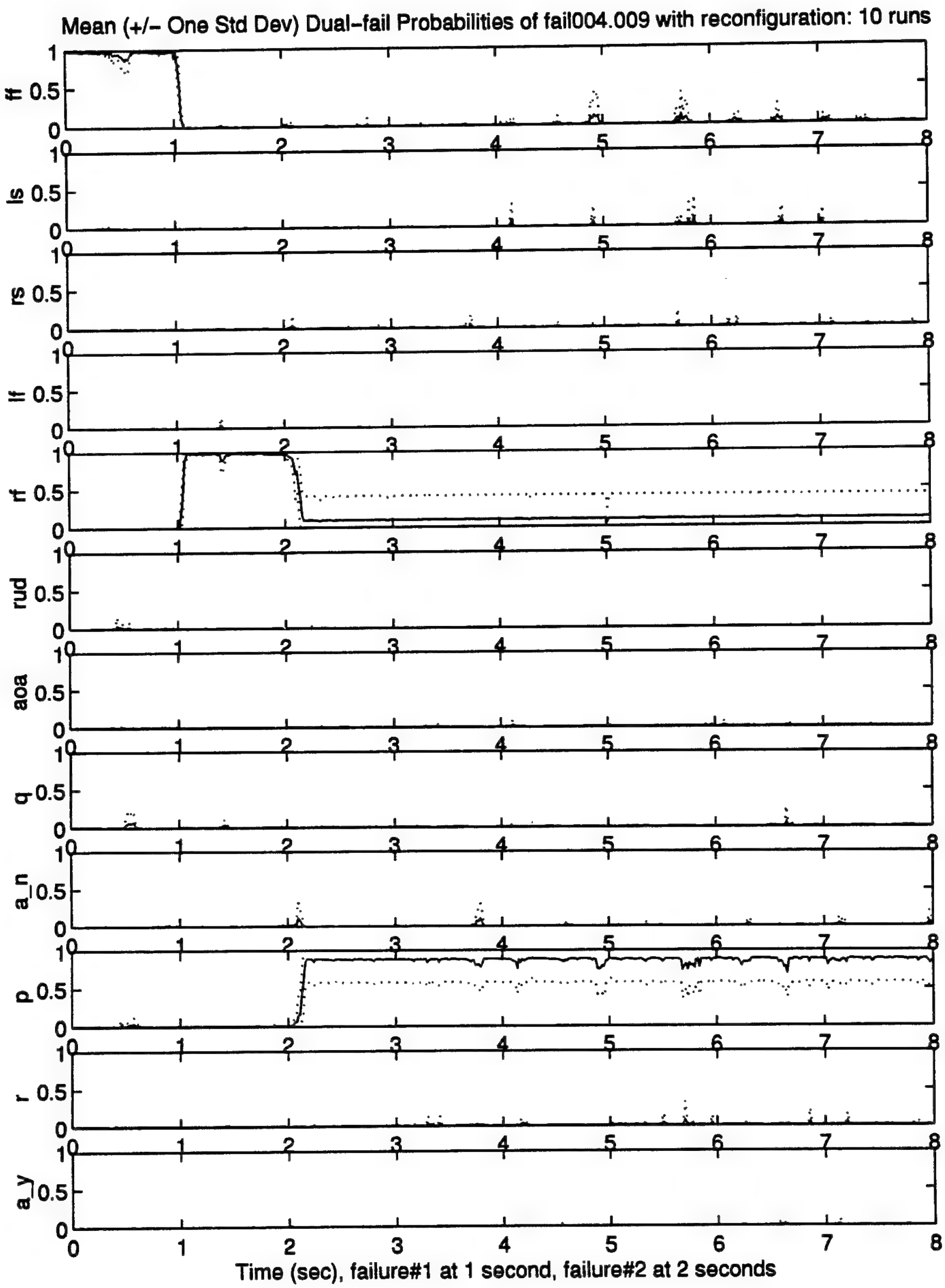

Mean (+/- One Std Dev) Dual-fail Probabilities of fail004.006 with reconfiguration: 10 runs
rf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



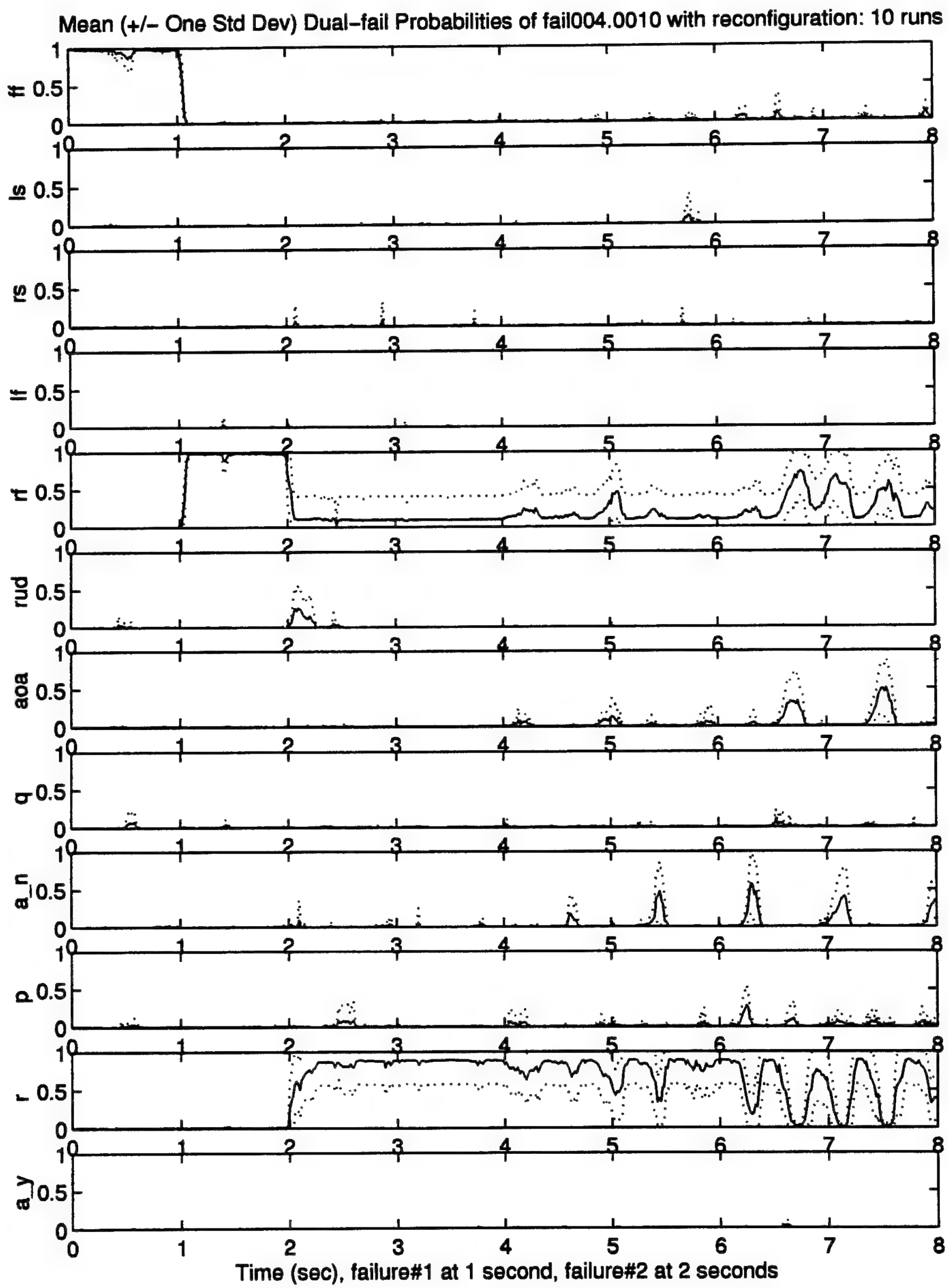
Mean (+/- One Std Dev) Dual-fail Probabilities of fail004.007 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0.5
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



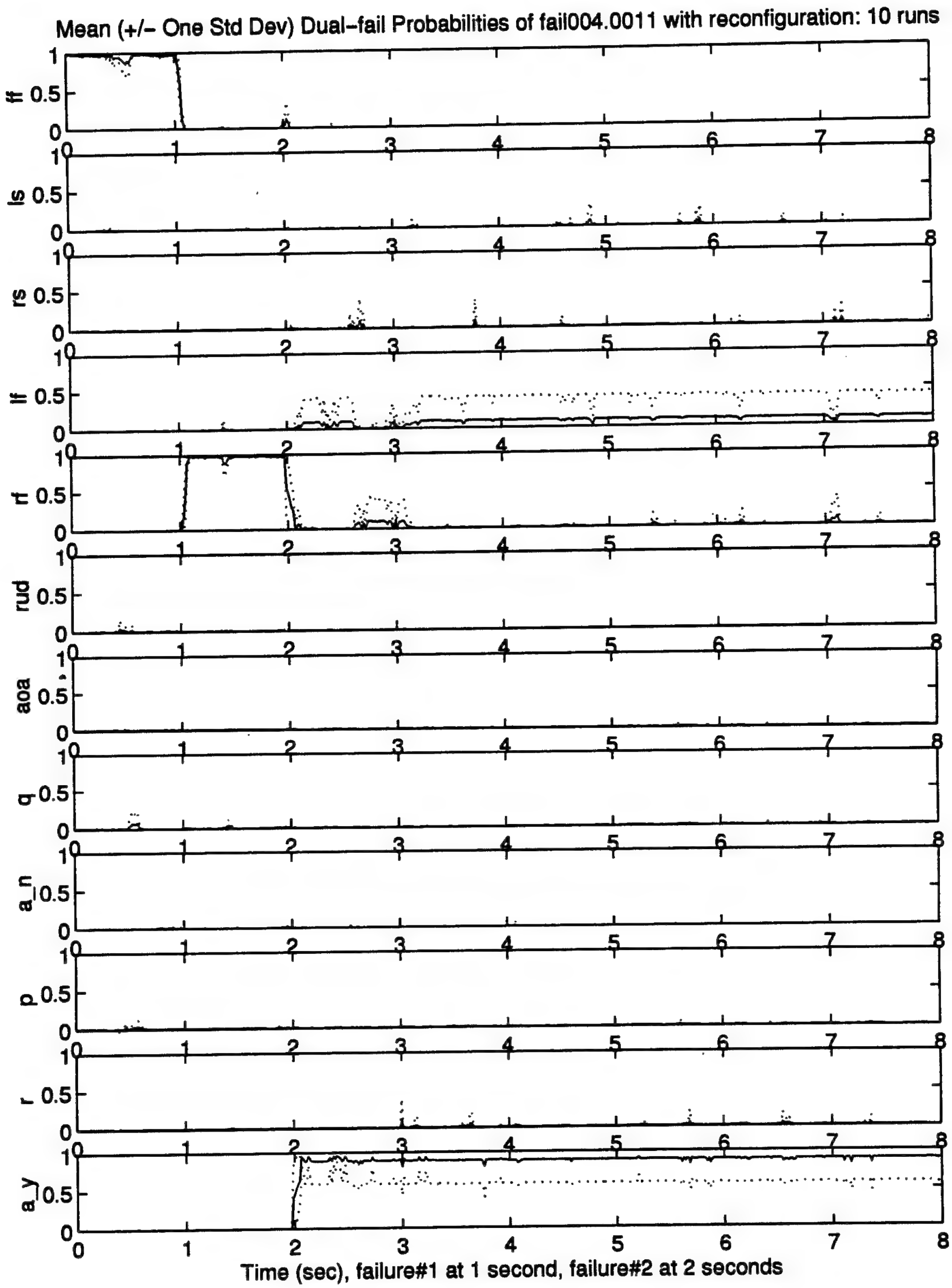
Mean (+/- One Std Dev) Dual-fail Probabilities of fail004.008 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



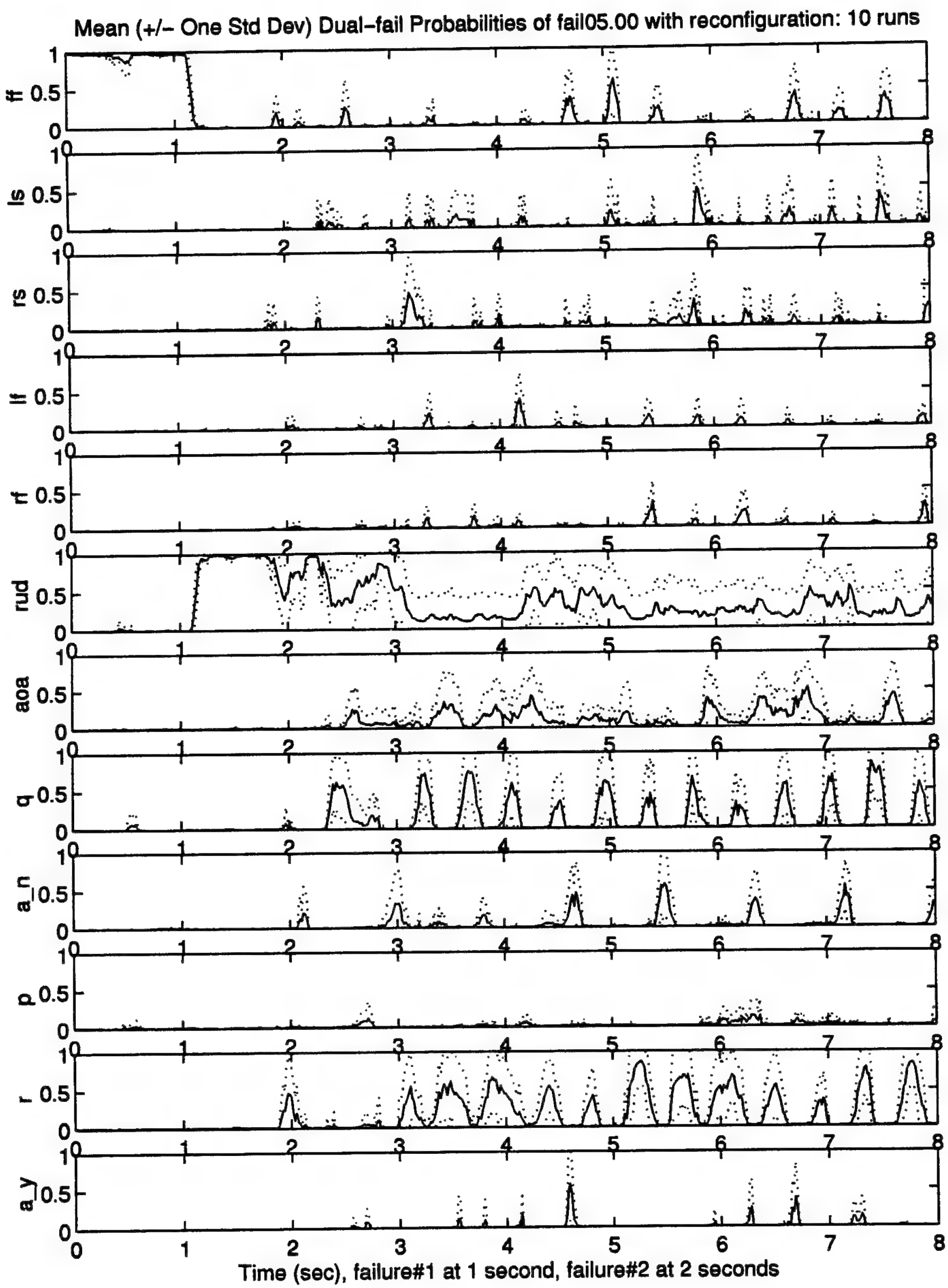
Mean (+/- One Std Dev) Dual-fail Probabilities of fail004.009 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

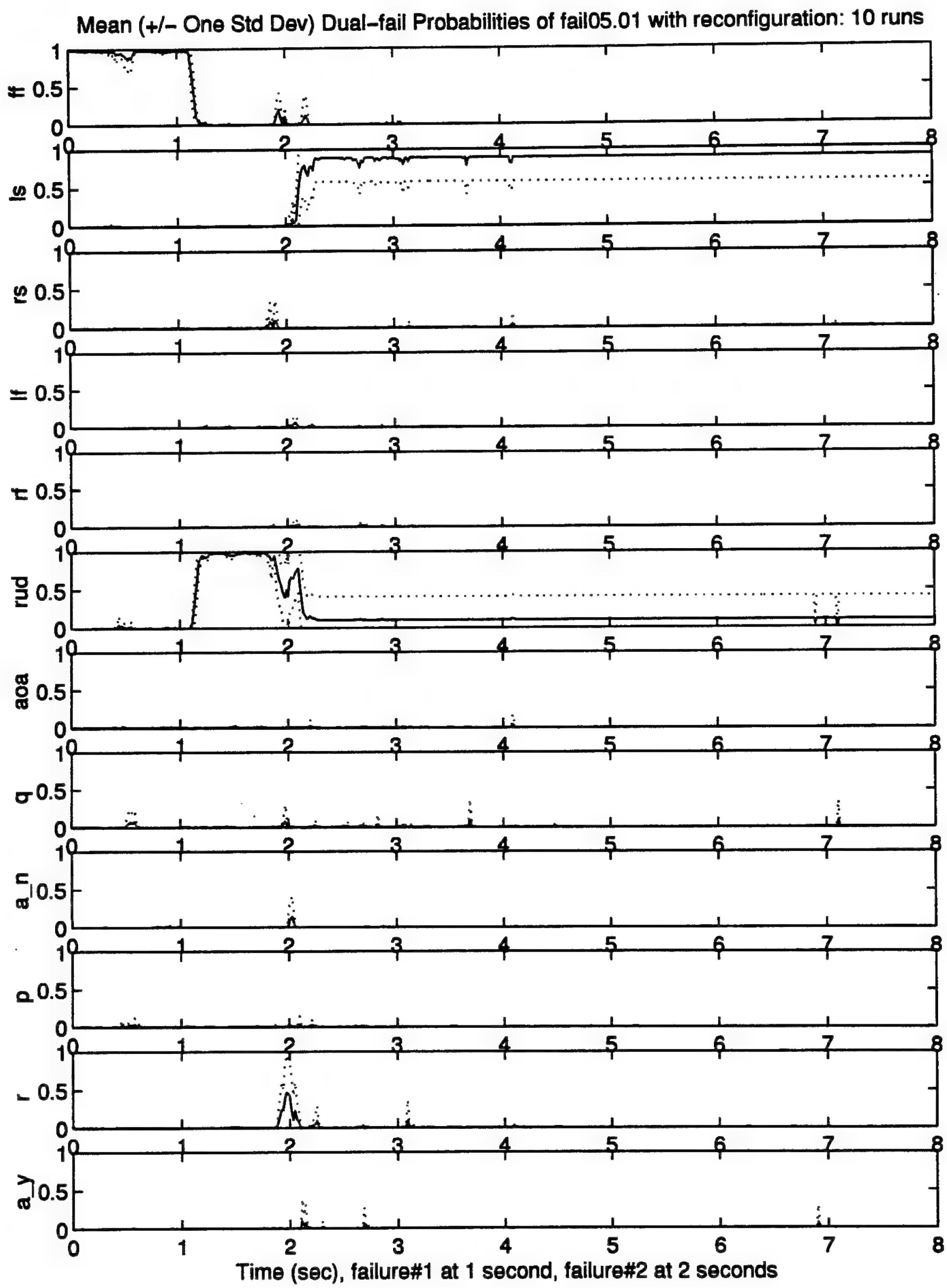


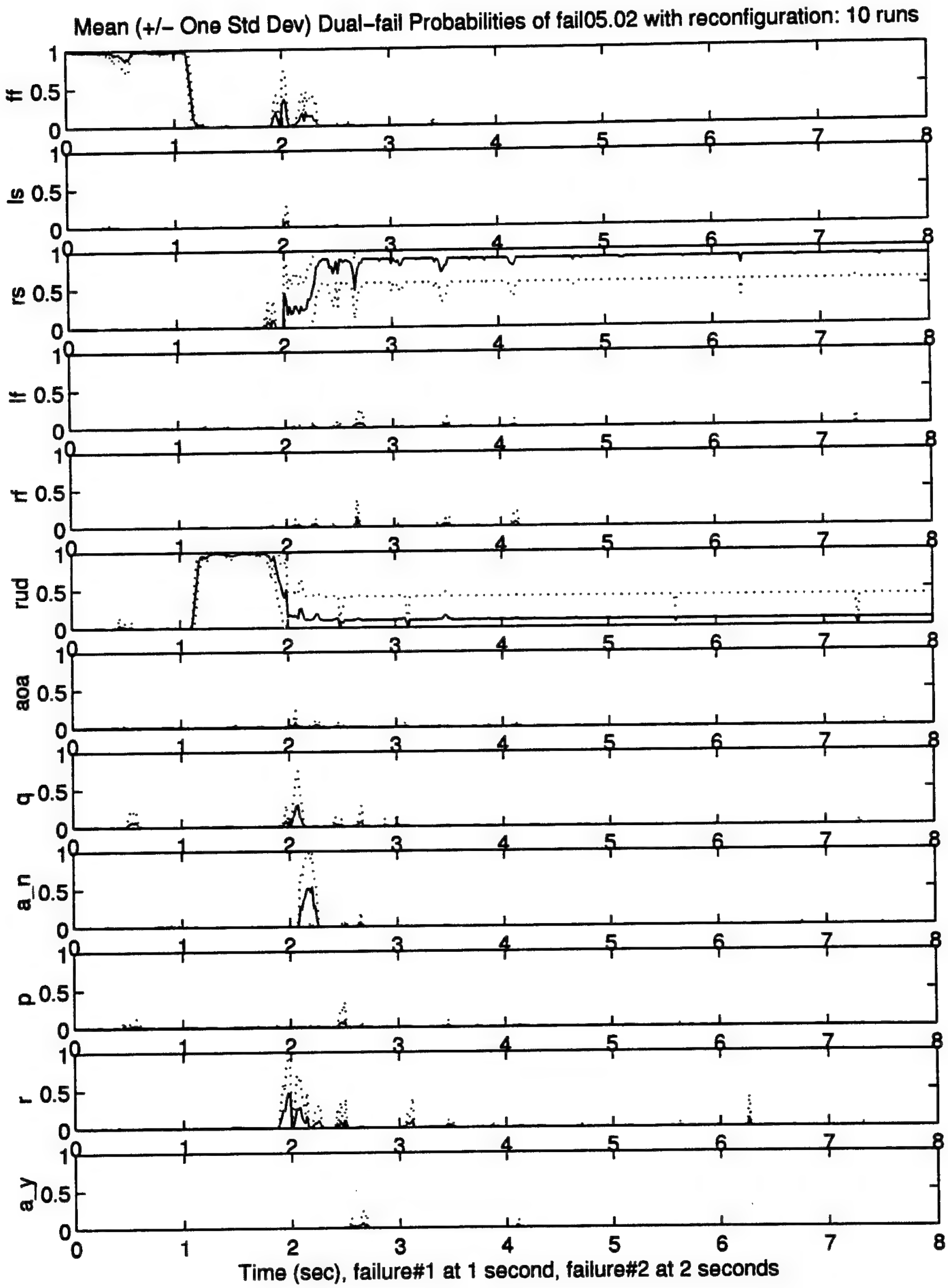
Mean (+/- One Std Dev) Dual-fail Probabilities of fail004.0010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

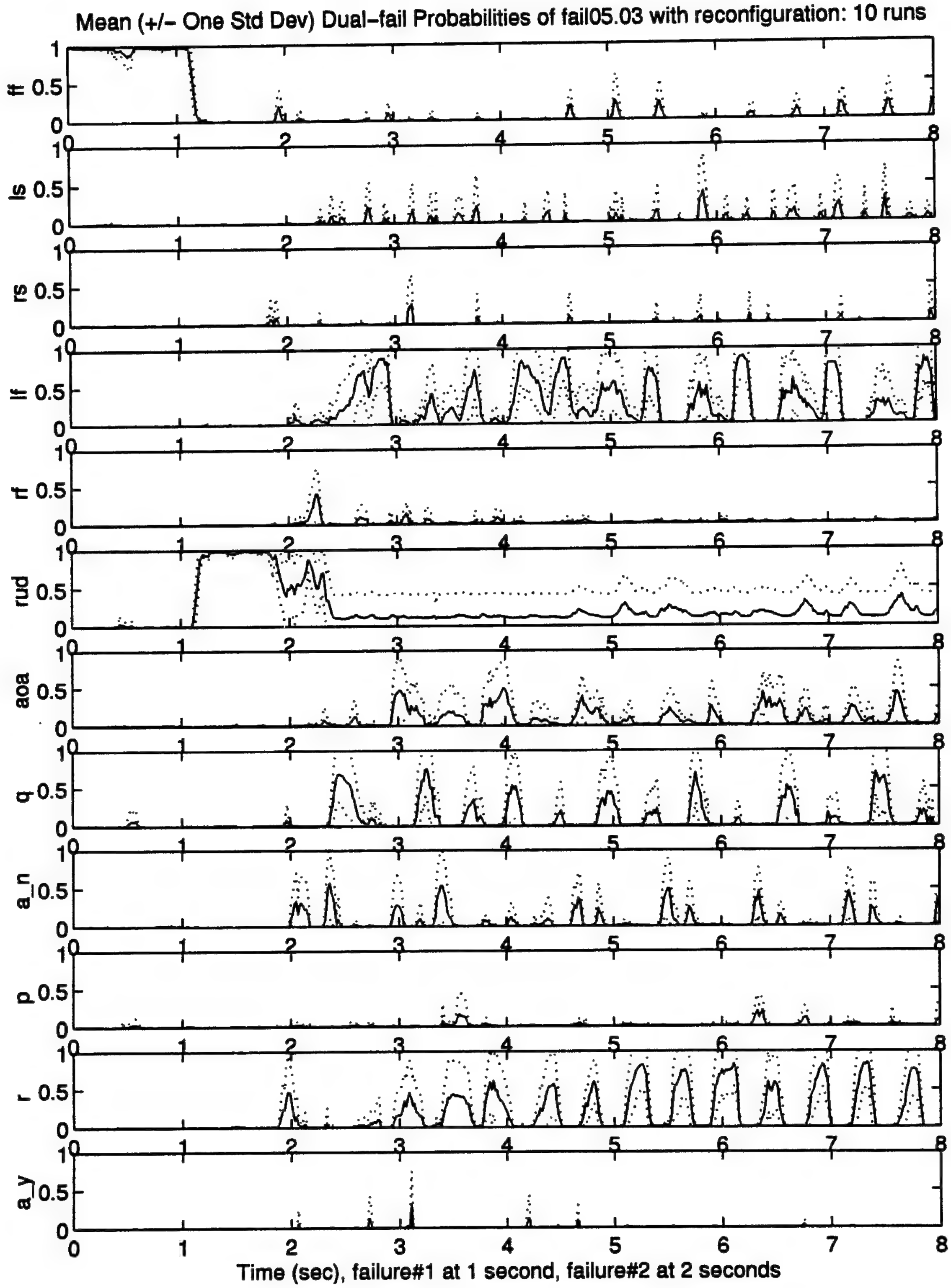


Mean (+/- One Std Dev) Dual-fail Probabilities of fail004.0011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

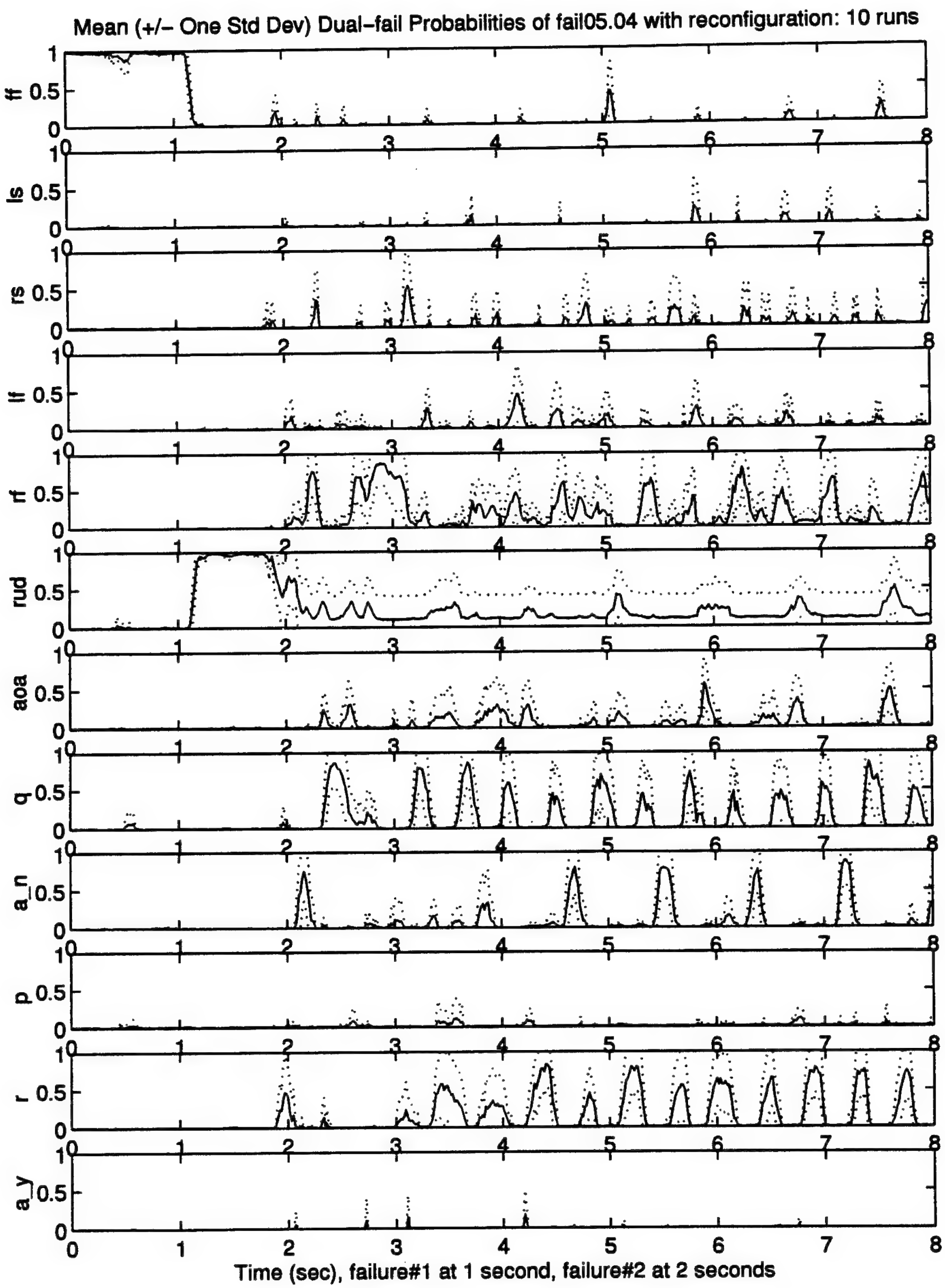

Mean (+/- One Std Dev) Dual-fail Probabilities of fail05.00 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail05.01 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

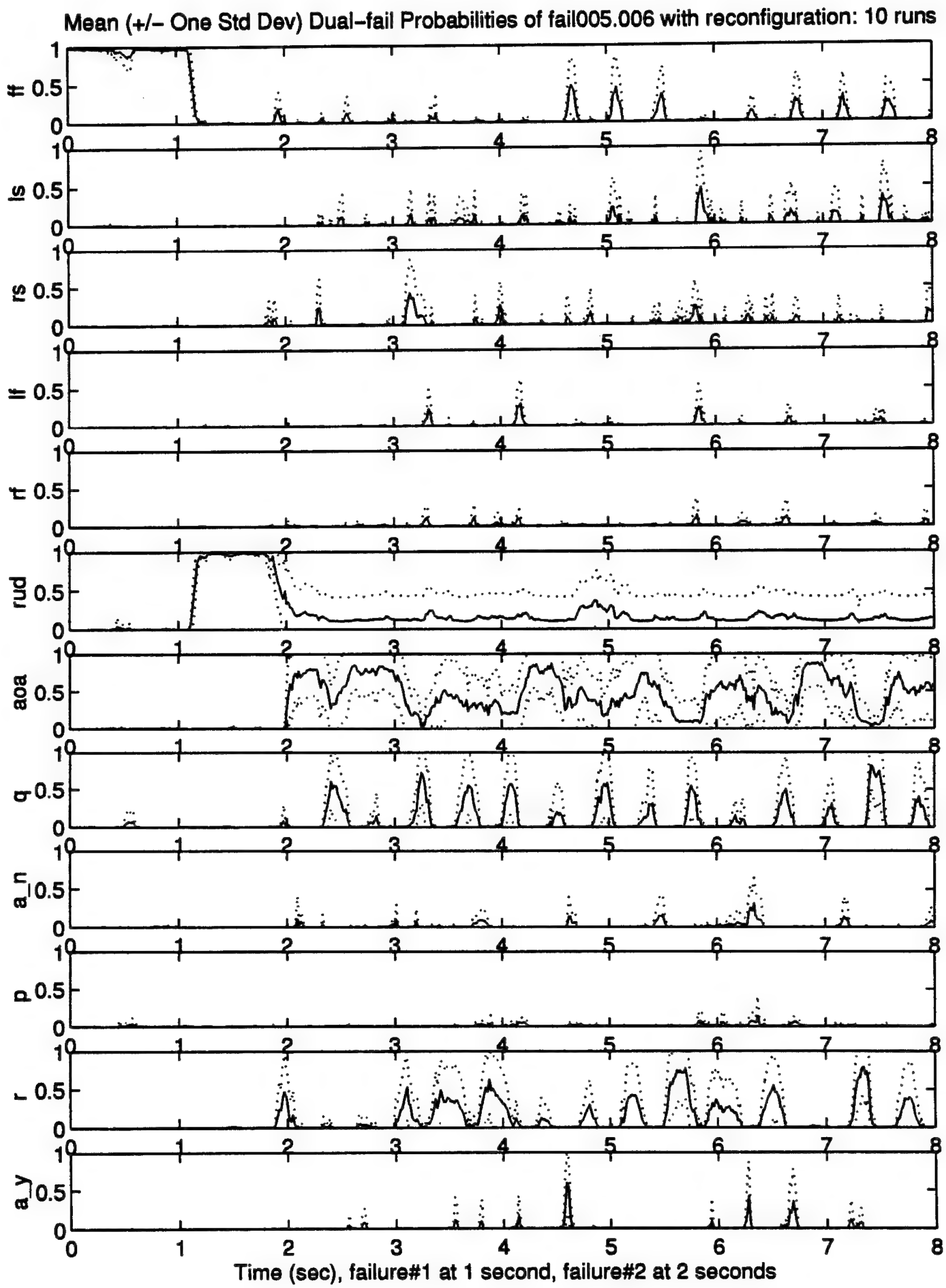

Mean (+/- One Std Dev) Dual-fail Probabilities of fail05.02 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

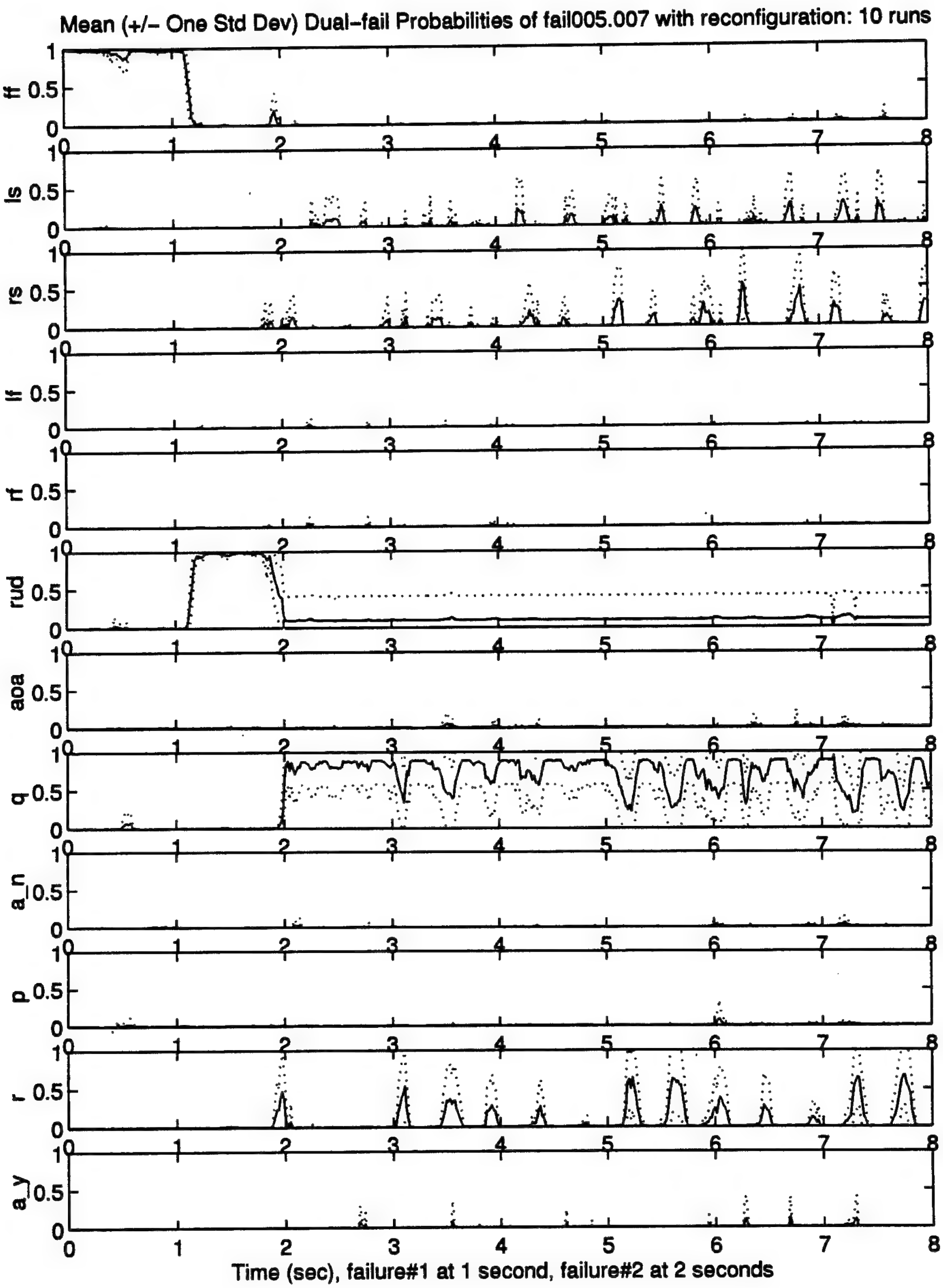


Mean (+/- One Std Dev) Dual-fail Probabilities of fail05.03 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

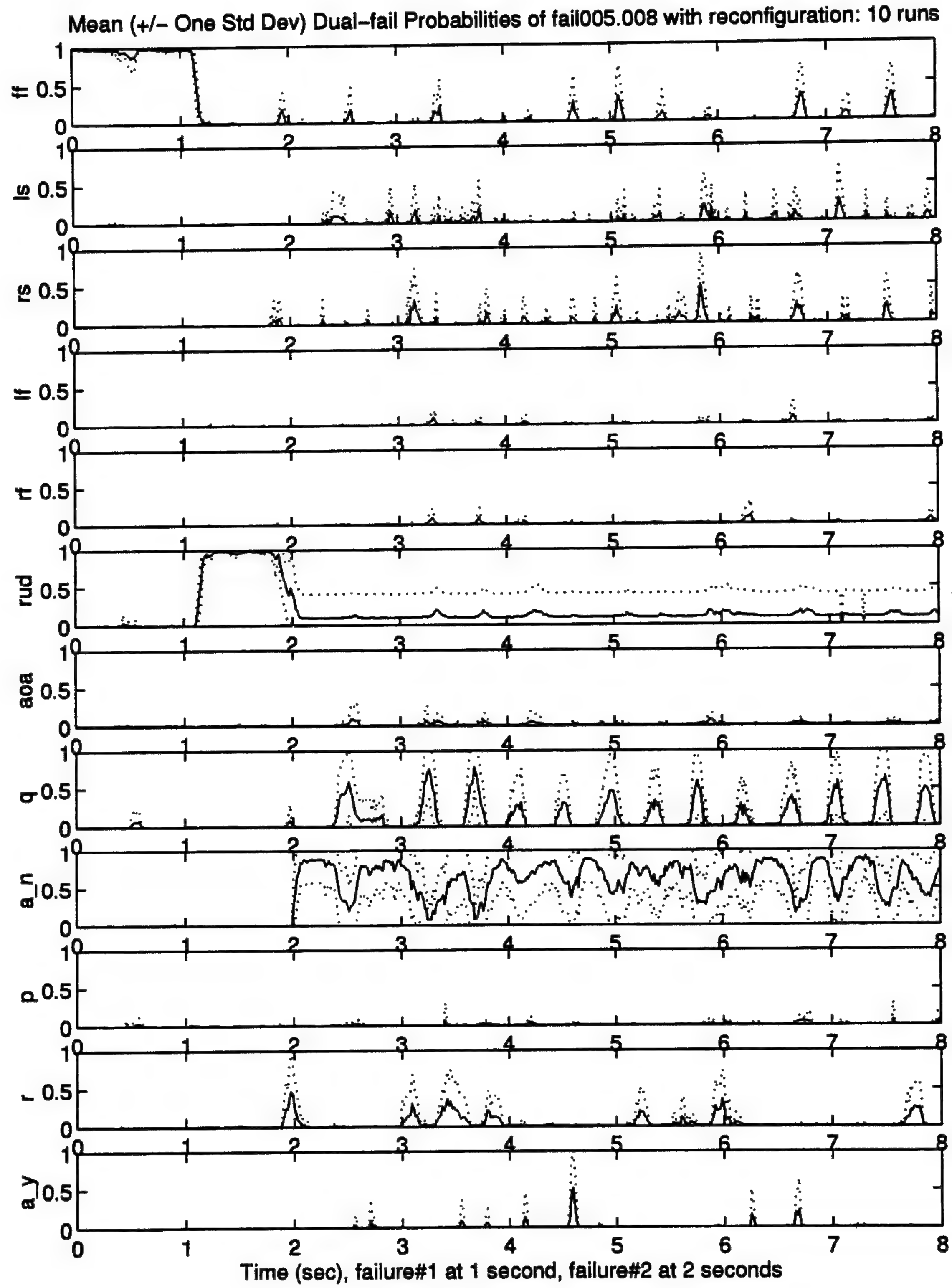


Mean (+/- One Std Dev) Dual-fail Probabilities of fail05.04 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

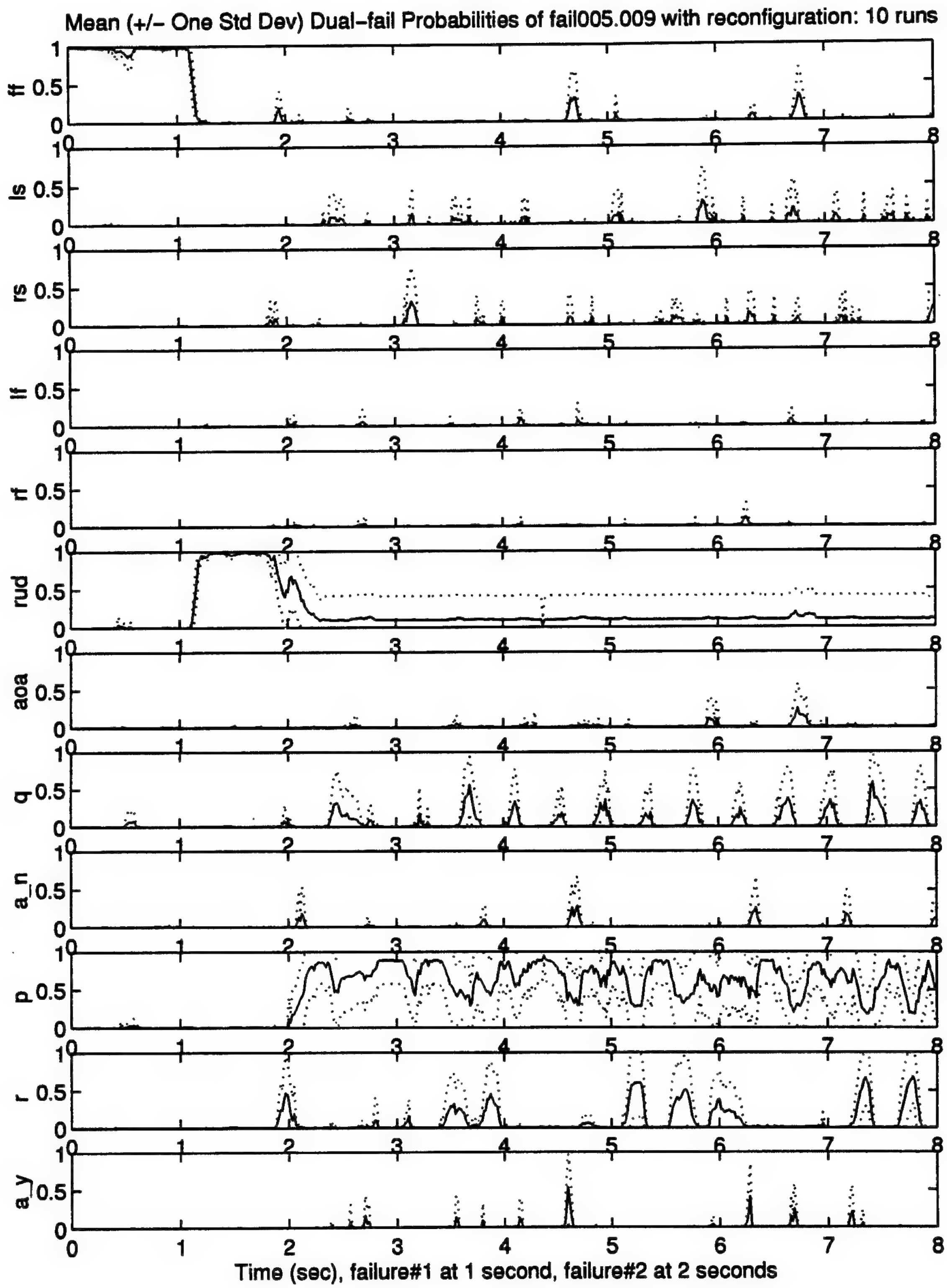

Mean (+/- One Std Dev) Dual-fail Probabilities of fail005.006 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

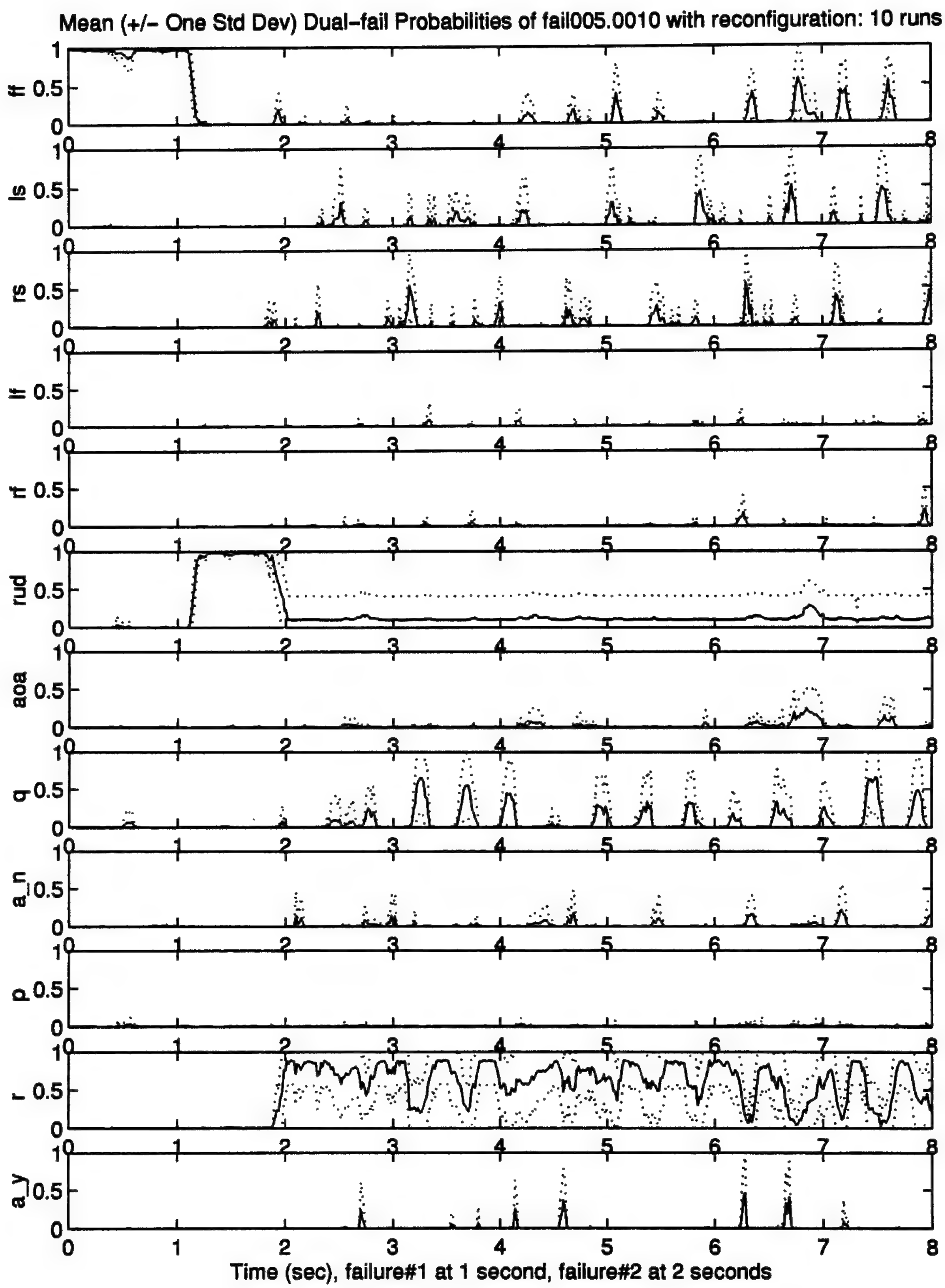


Mean (+/- One Std Dev) Dual-fail Probabilities of fail005.007 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

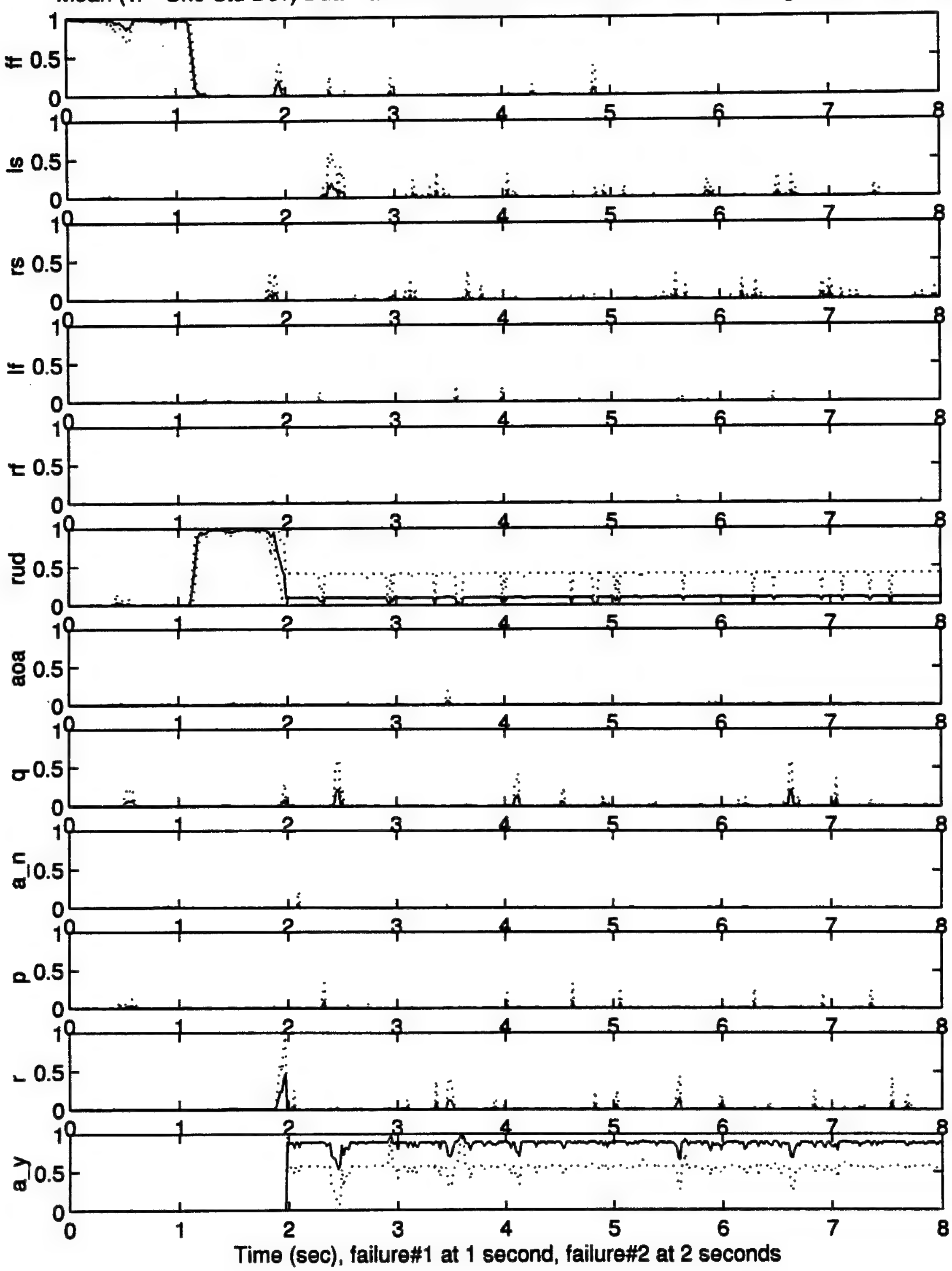


Mean (+/- One Std Dev) Dual-fail Probabilities of fail005.008 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail005.009 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail005.0010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

Mean (+/- One Std Dev) Dual-fail Probabilities of fail005.0011 with reconfiguration: 10 runs



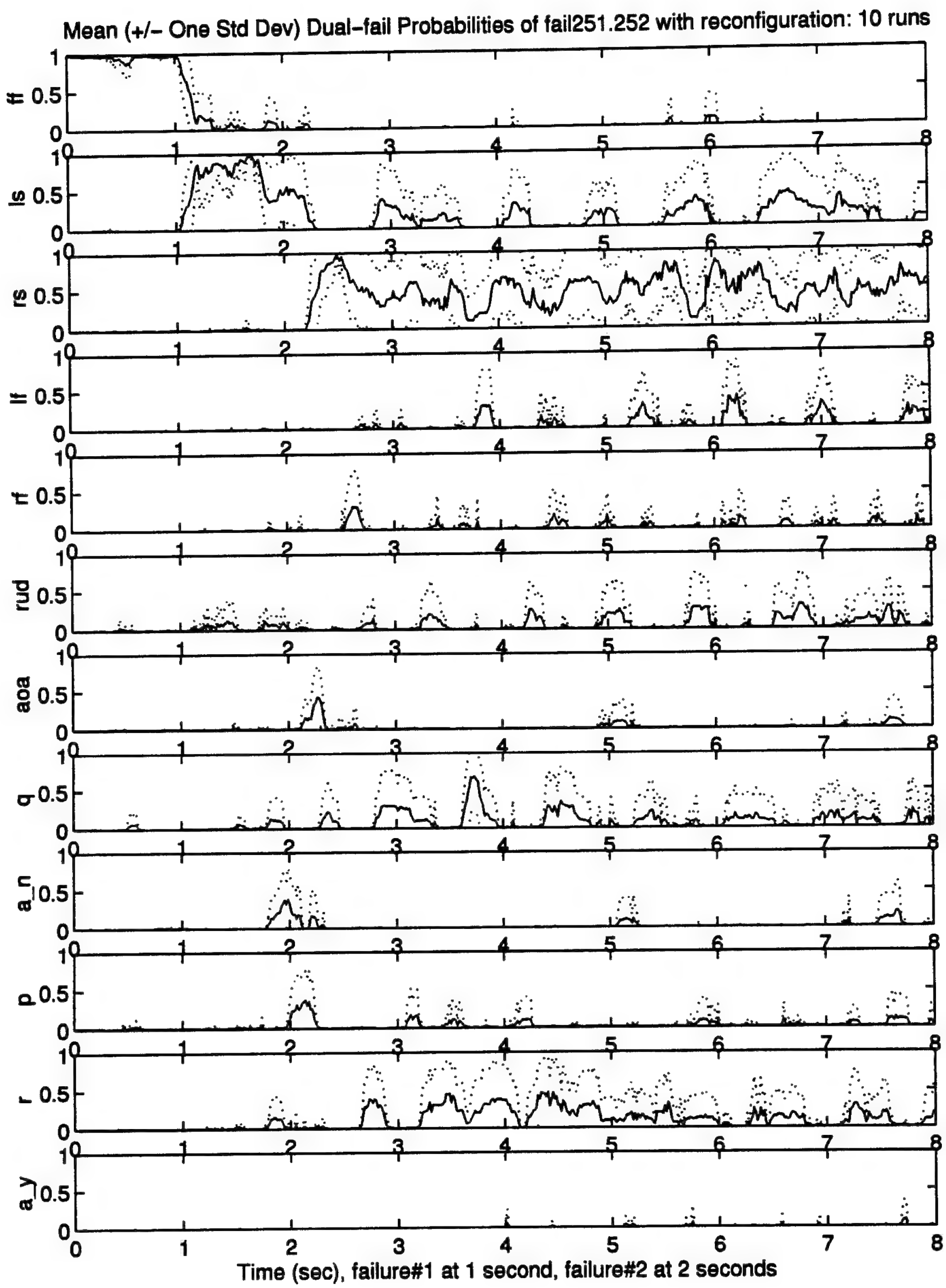
Appendix D.2: Dual, 75% Actuator (ε =.25) and 75%-Actuator / Total -Sensor Impairments, Control Redistribution 'ON', Dither 'ON', No Maneuvers

This appendix contains the individual probability plots for "75% actuator / 75% actuator" and "75% actuator / total sensor" dual impairment scenarios, *with* Control Reconfiguration (Redistribution) and with control dithering (Section 4.12.3). The first impairment is inserted at 1 second, followed by the second impairment at 2 seconds, and in all cases, there is no aircraft maneuvering. Table D.2 on the following page lists the impairment cases, by case number, which are to be found in this appendix. The leftmost column of Table D.2 represents the first impairment occurring at 1 second, while the top row represents the second impairment occurring at 2 seconds. The table entries list the failure codes found in the plot titles for the failure case represented by the table row and column. **Bold** entries correspond to cases of no second impairment. As an example, the entry for a 75% left stabilator (LS) impairment at 1 second, followed by a 75% right flaperon (RF) impairment at 2 seconds is found in entry '(LS, RF)' in the table, and the corresponding failure case is 'fail251.254'. The convention was to use effectiveness, ε, in naming the plots, and hence 'fail<u>25</u>1.<u>25</u>4' corresponds to 25% actuator *effectiveness*, or a 75% actuator impairment. The probability plot will contain this code ('fail251.254') in the plot title. In fact, for this specific case, the plot title is: "Mean (+ / - One Std Dev) Dual-fail Probabilities of fail251.254 with reconfiguration: 10 runs". The reader is reminded that, after the switch to the Level '1' filter bank, the meanings of the probability traces in the plots (except for the fully functional trace, which retains the same meaning) change to that of the first impairment *plus* the second impairment.

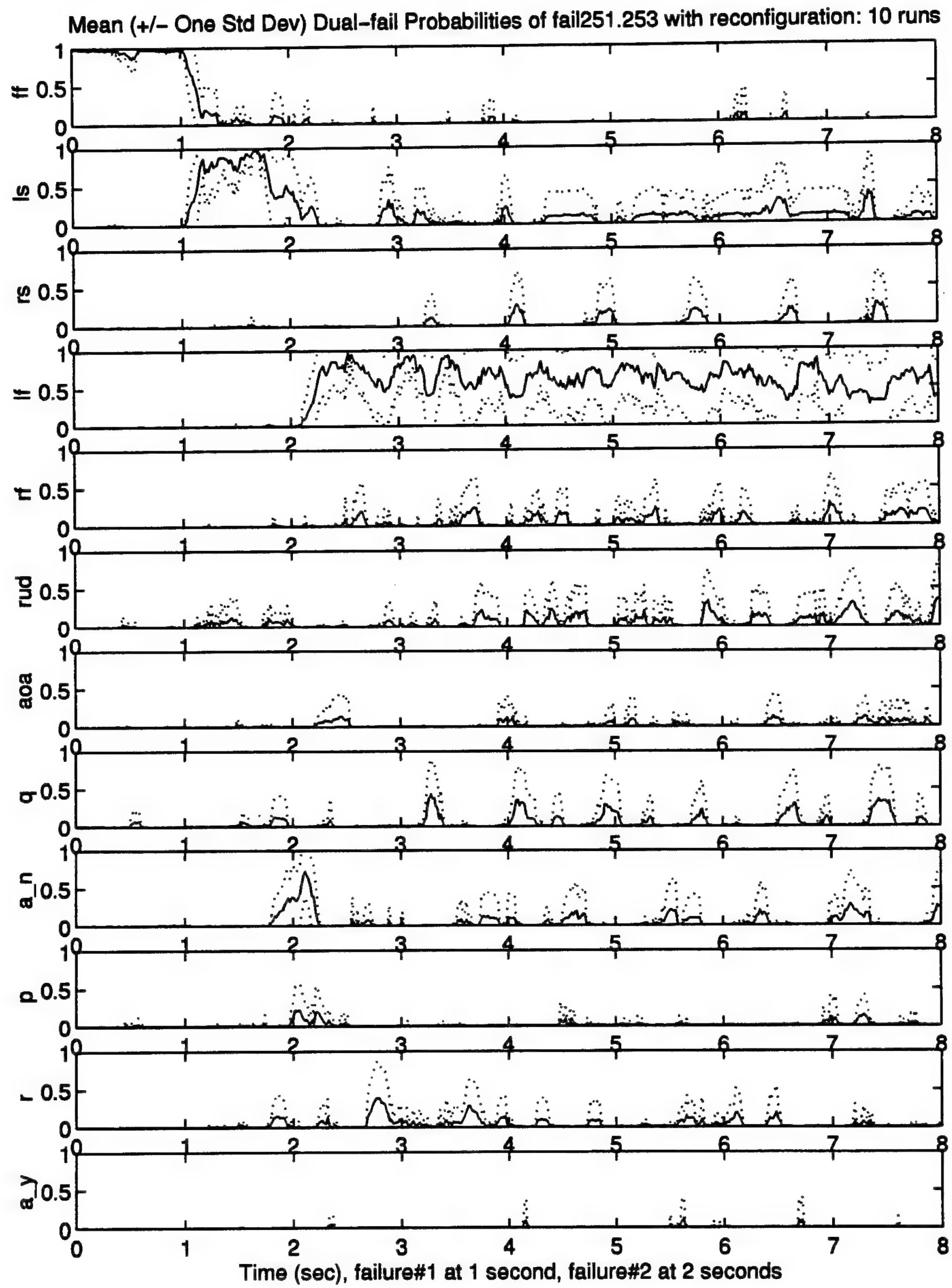
Second Impairment

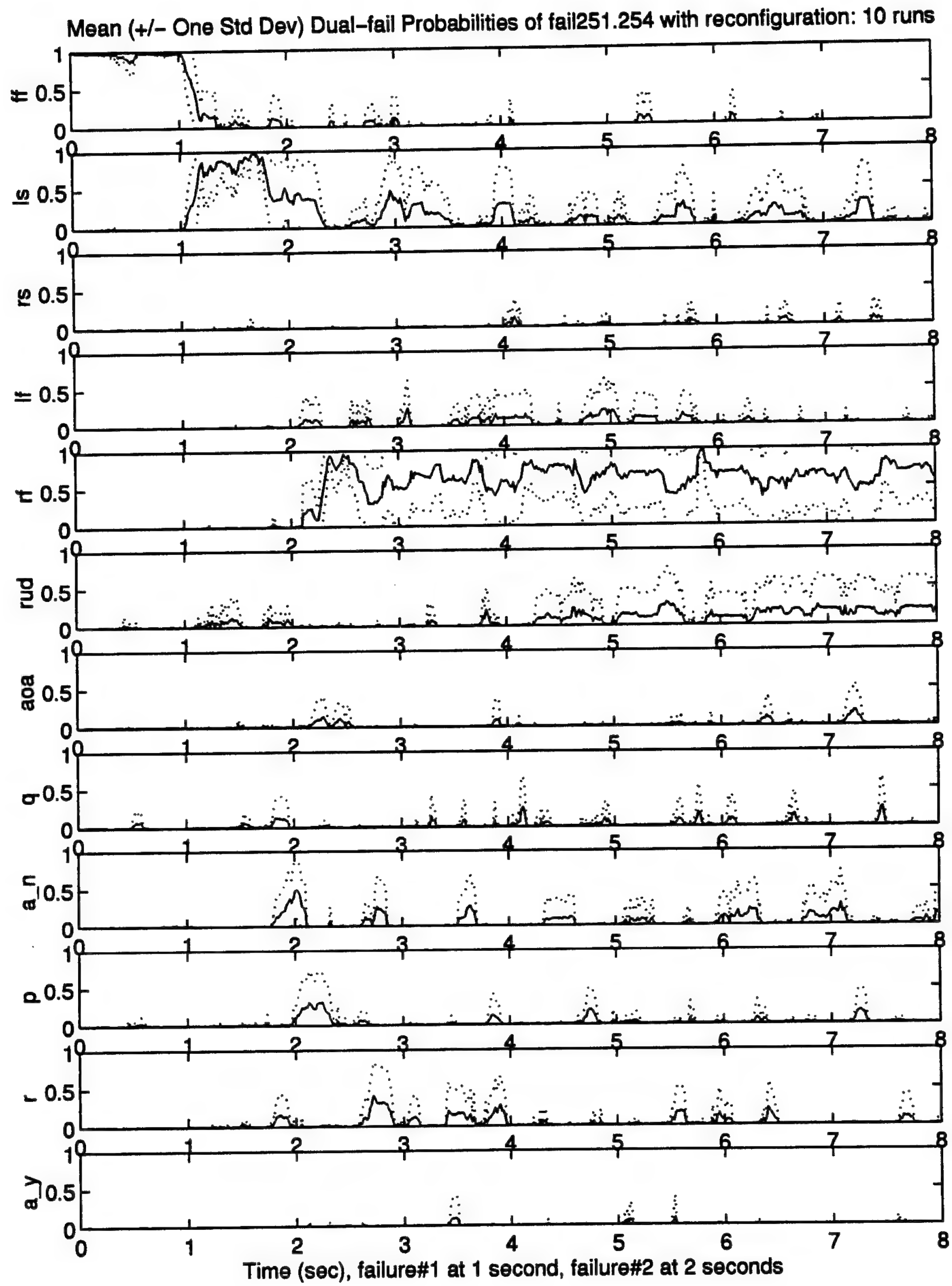
	LS (75%)	RS (75%)	LF (75%)	RF (75%)	RUD (75%)	AOA (100%)	Q (100%)	A_n (100%)	P (100%)	R (100%)	A_y (100%)
LS (75%)	**fail251.250**	fail251.252	fail251.253	fail251.254	fail251.255	fail251.06	fail251.07	fail251.08	fail251.09	fail251.010	fail251.011
RS (75%)	fail252.251	**fail252.250**	fail252.253	fail252.254	fail252.255	fail252.06	fail252.07	fail252.08	fail252.09	fail252.010	fail252.011
LF (75%)	fail253.251	fail253.252	**fail253.250**	fail253.254	fail253.255	fail253.06	fail253.07	fail253.08	fail253.09	fail253.010	fail253.011
RF (75%)	fail254.251	fai254.252	fail254.253	**fail254.250**	fail254.255	fail254.06	fail254.07	fail254.08	fail254.09	fail254.010	fail254.011
RUD (75%)	fail255.251	fail255.252	fail255.253	fail255.254	**fail255.250**	fail255.06	fail255.07	fail255.08	fail255.09	fail255.010	fail255.011

Table D.2 A Listing of All Probability Plots Found in Appendix D.2 by Failure Case

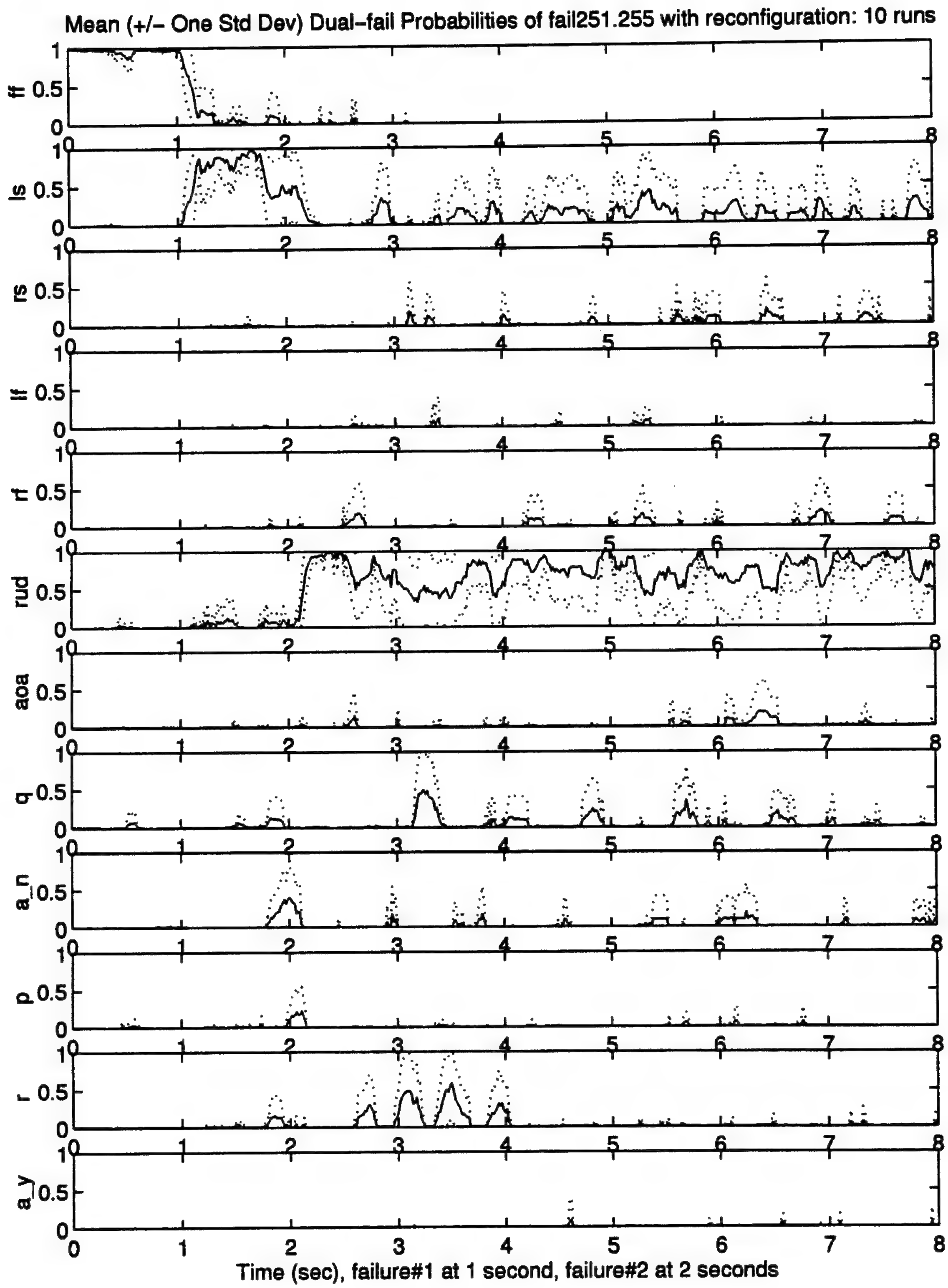


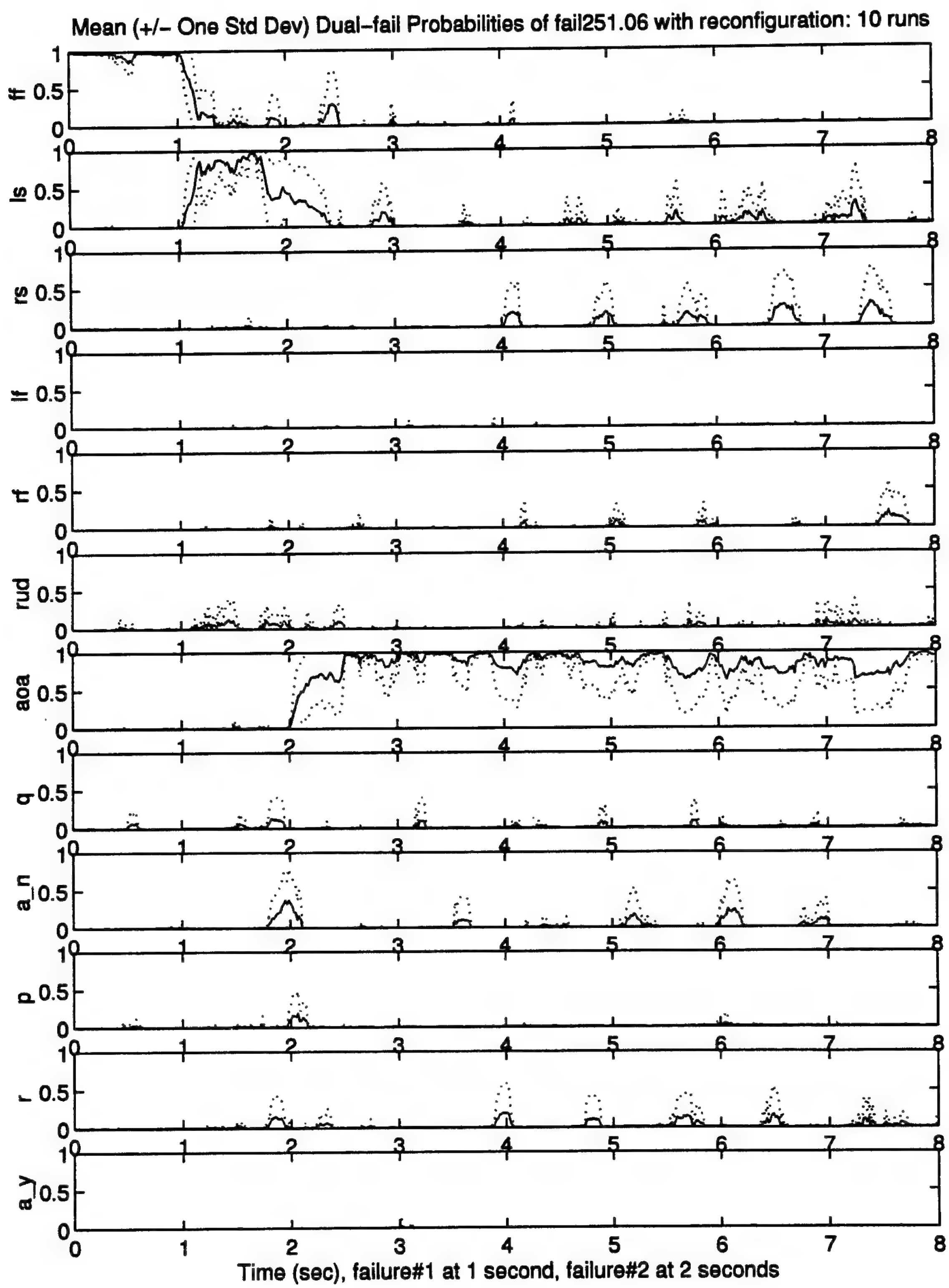
Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.252 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

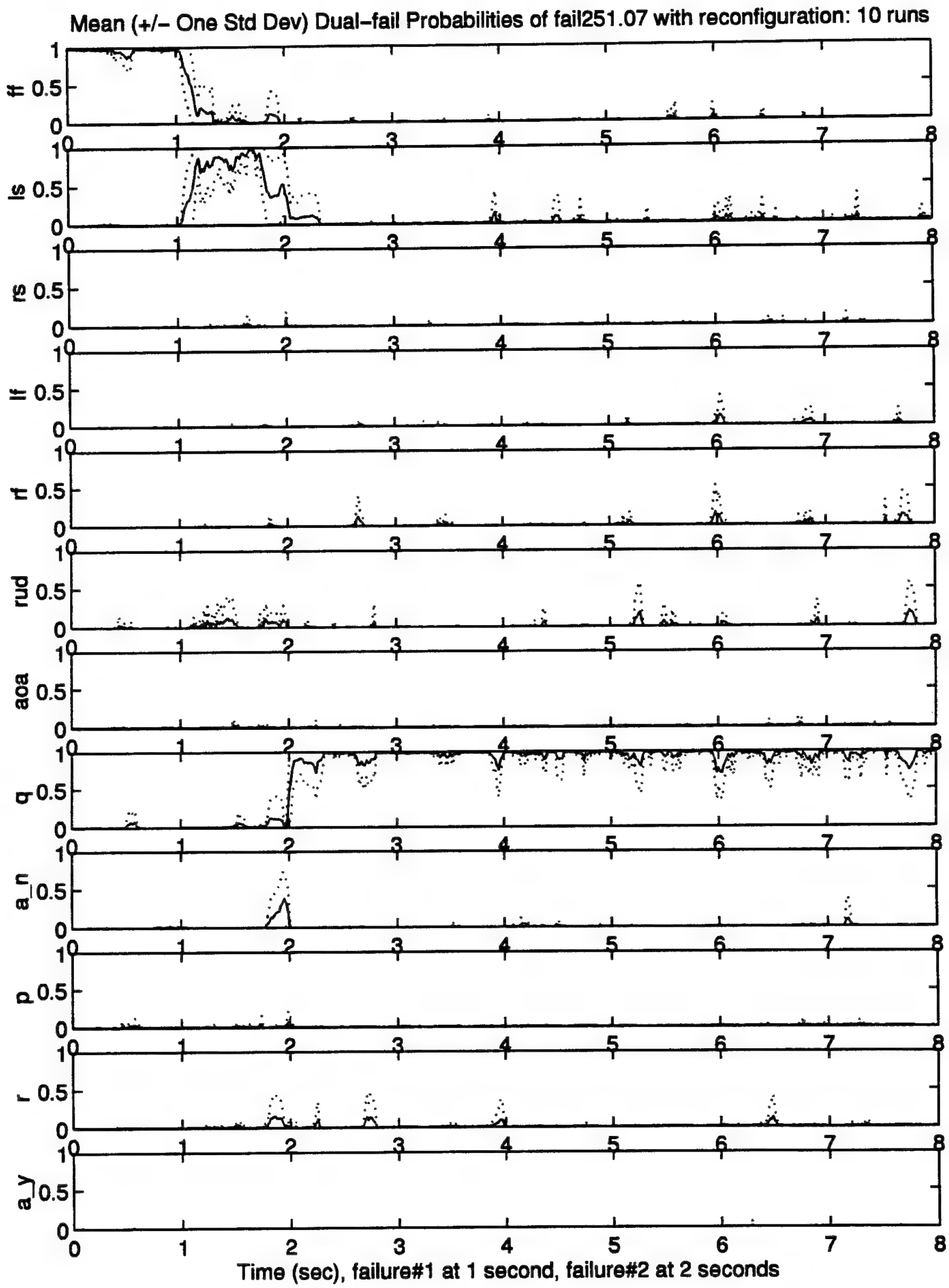

Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.253 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



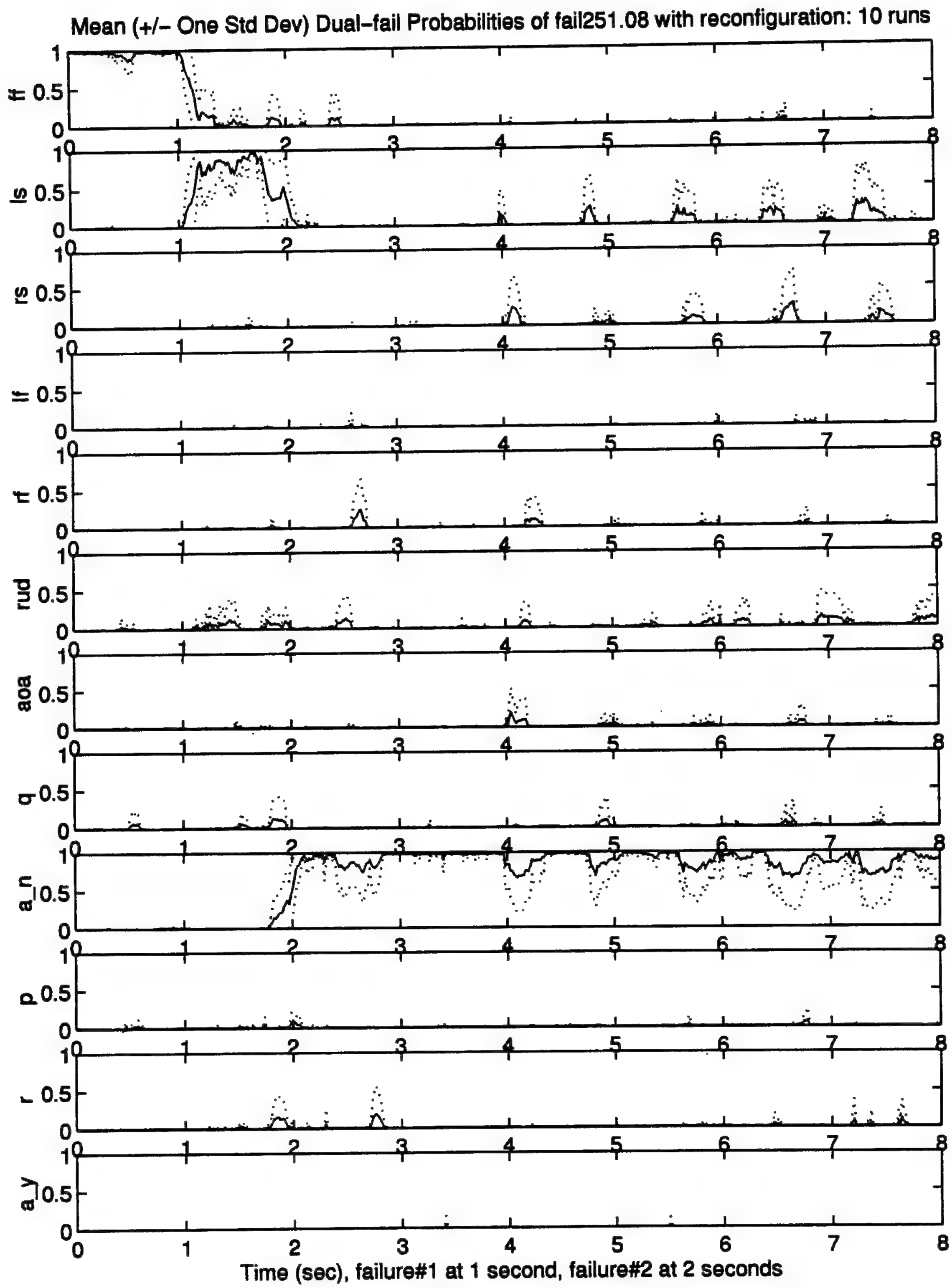
Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.254 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.255 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

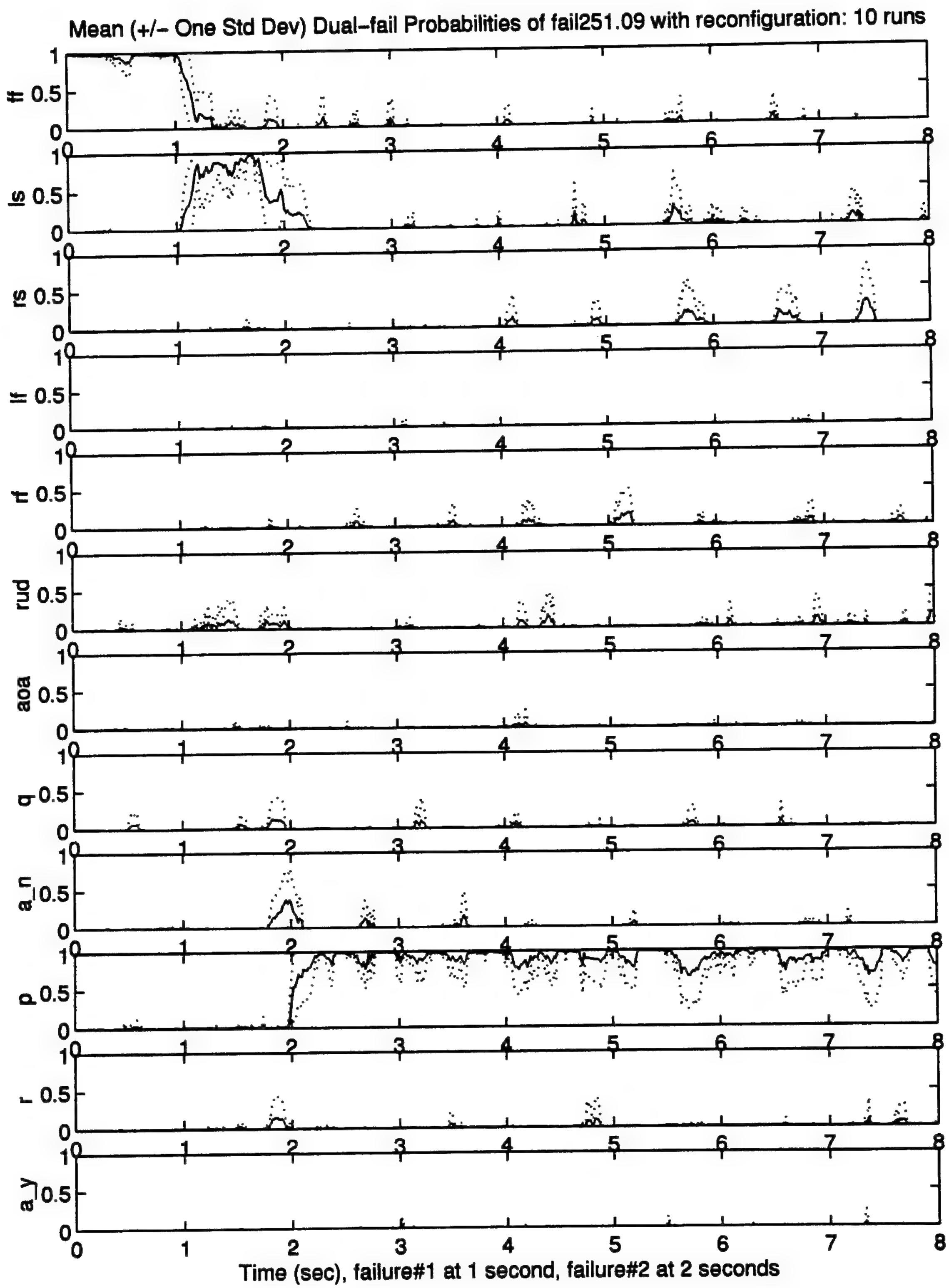

Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.06 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



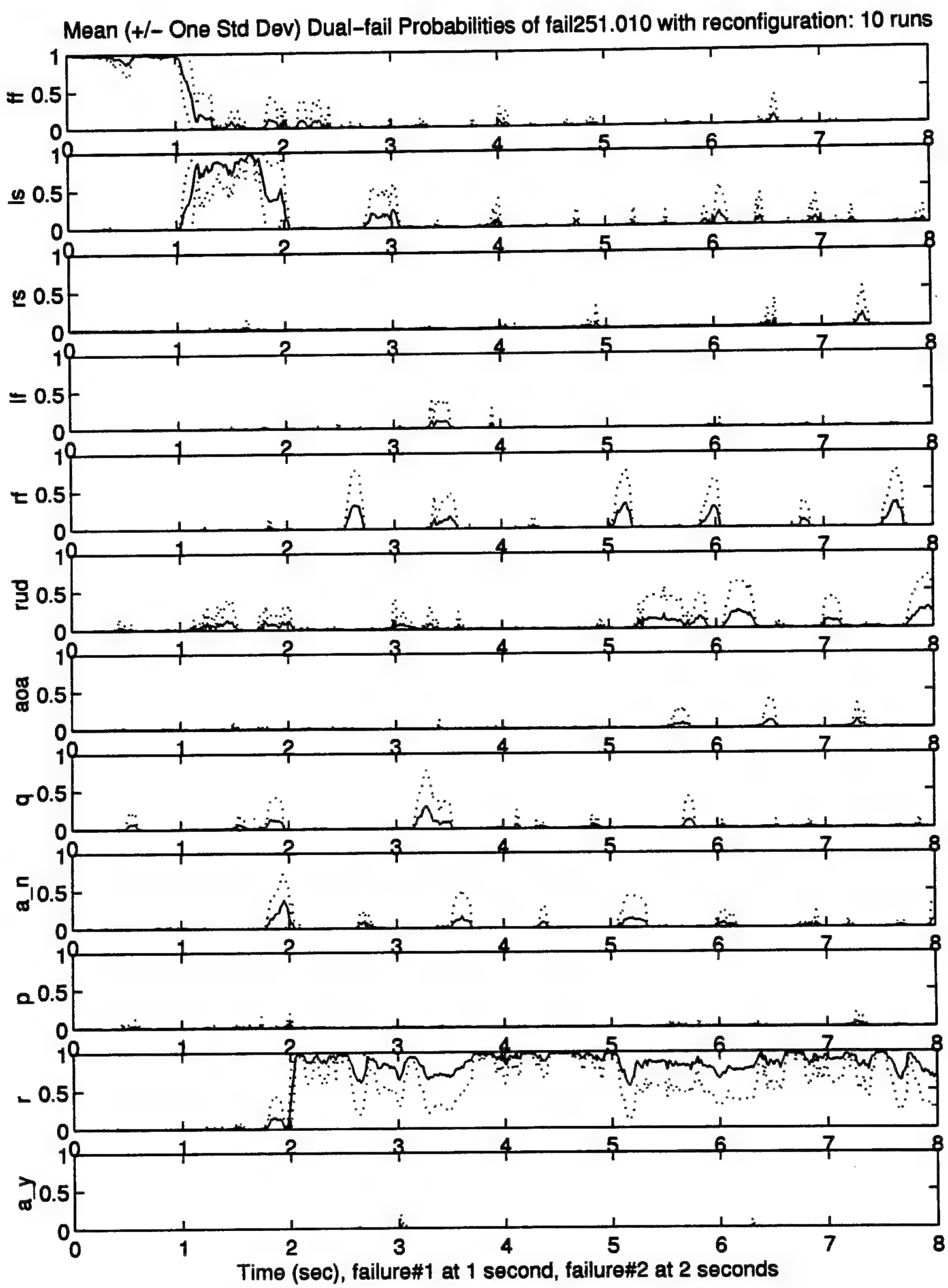
Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



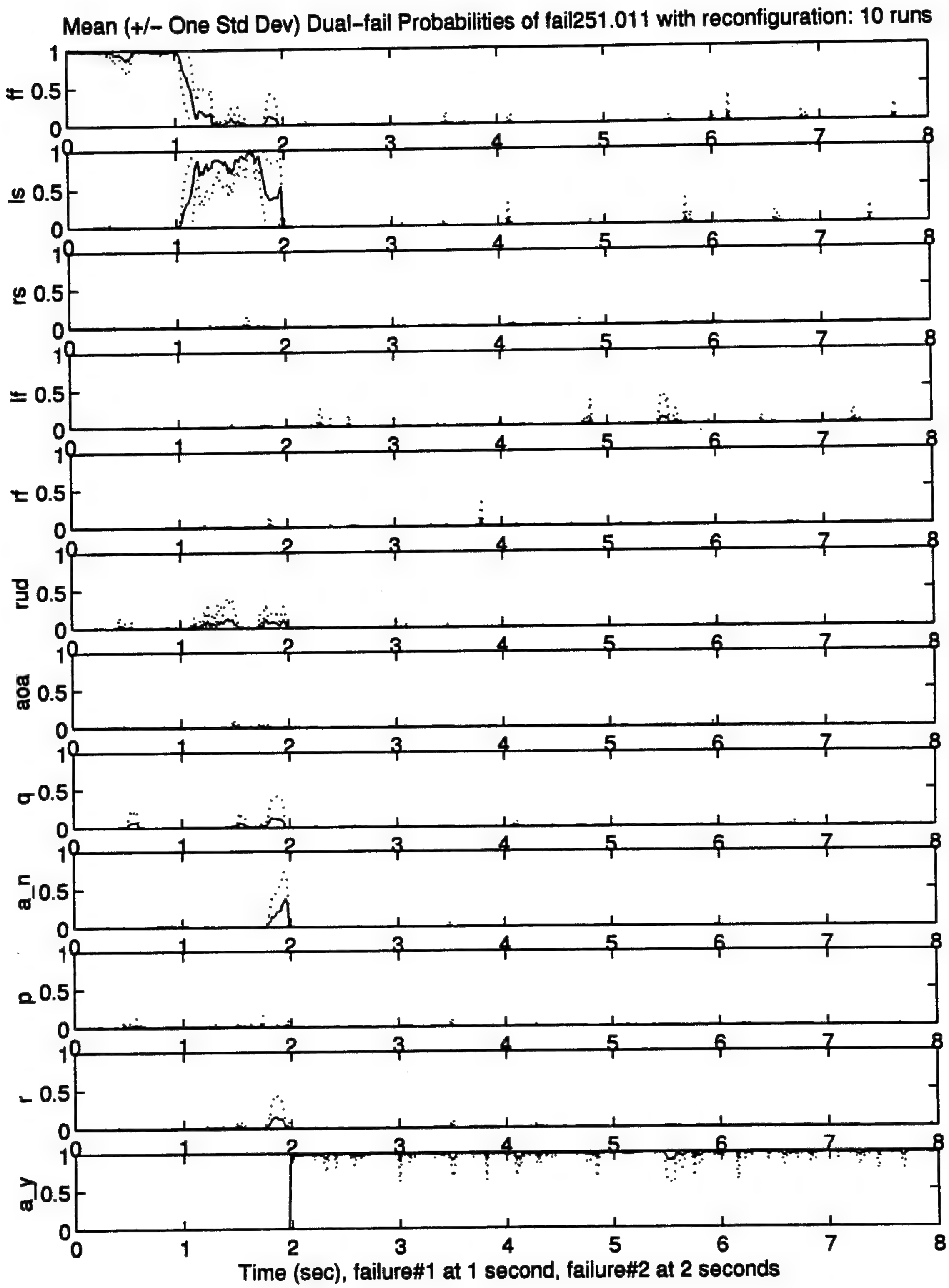
Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

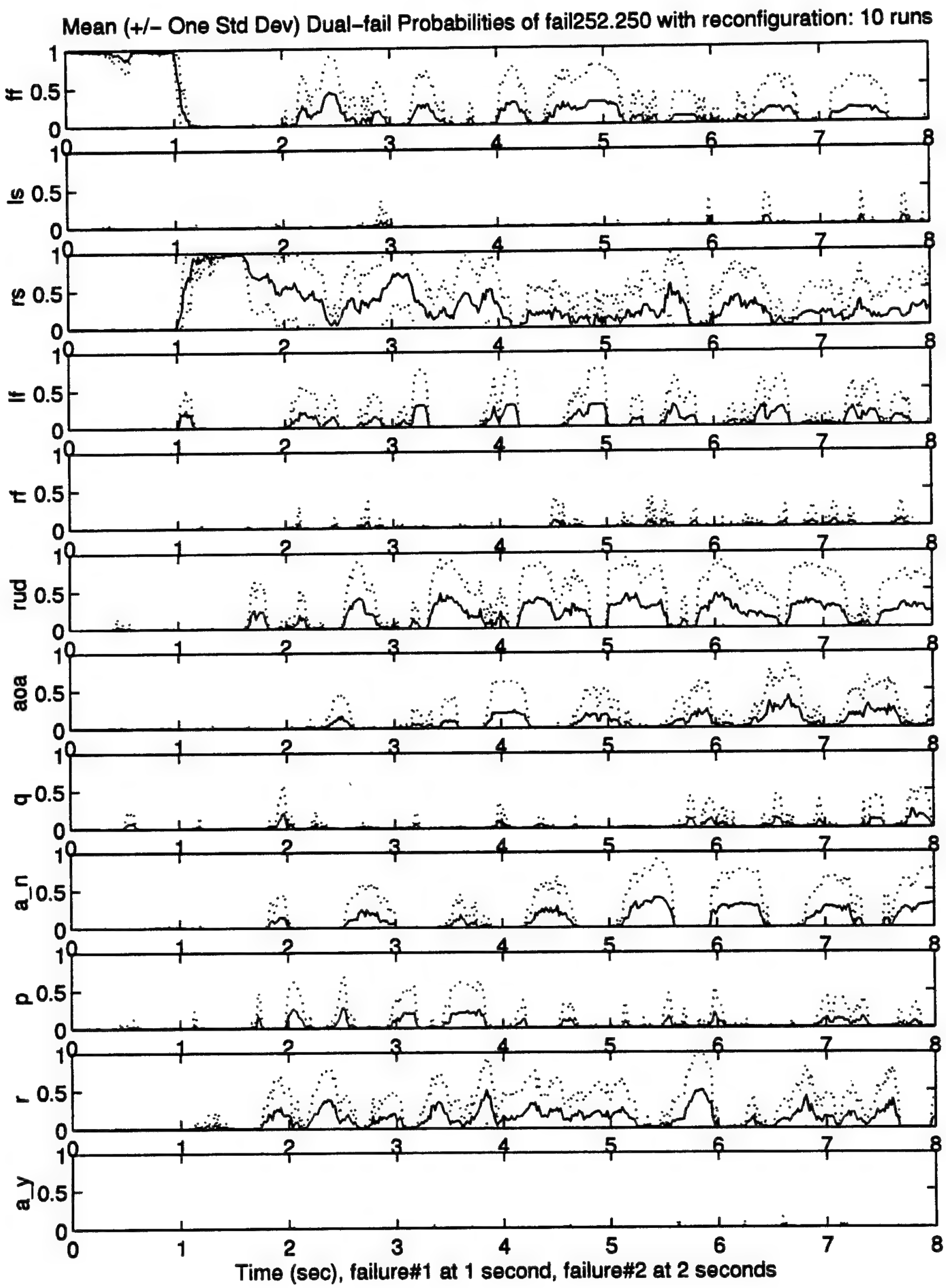


Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.09 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



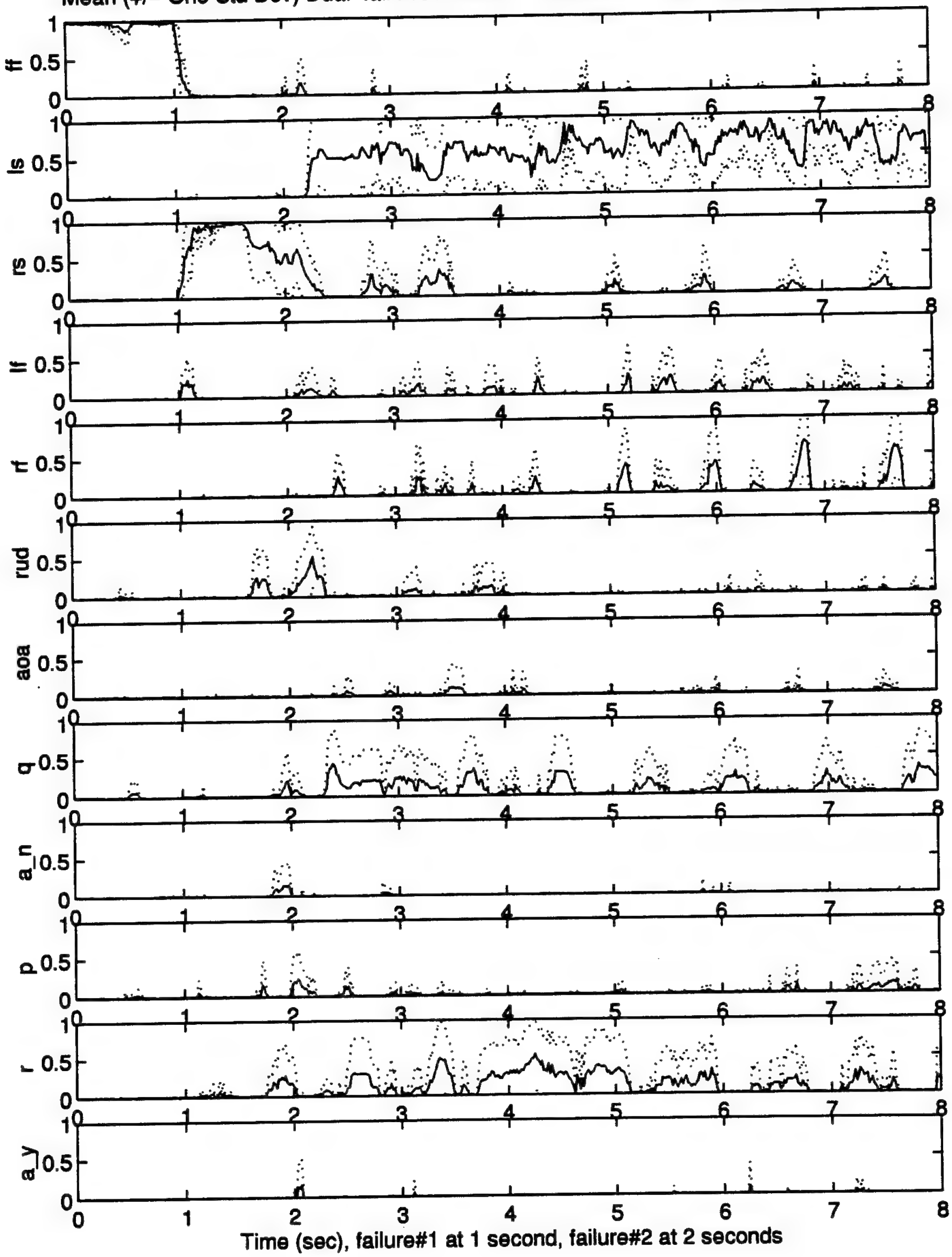
Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

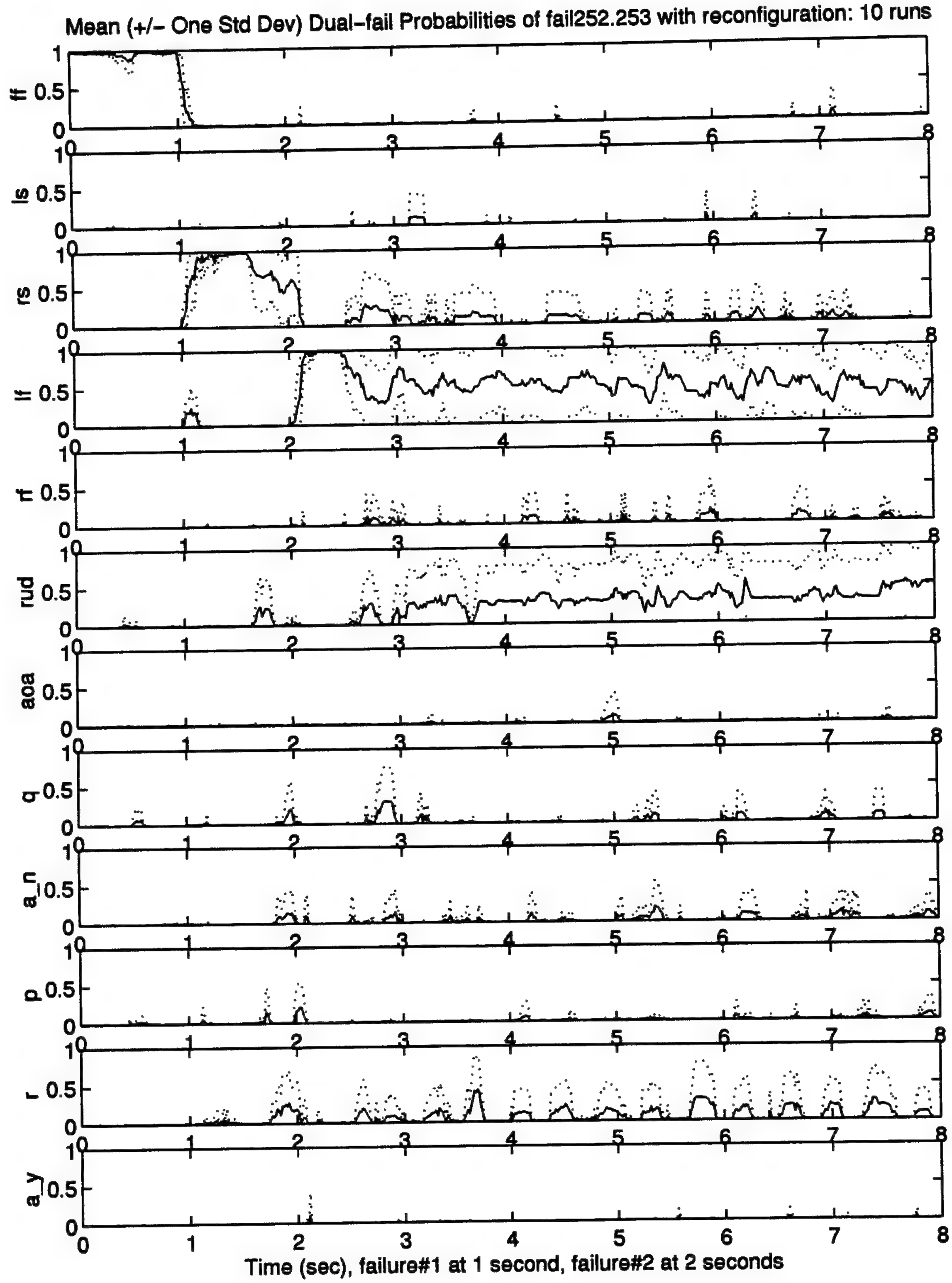

Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



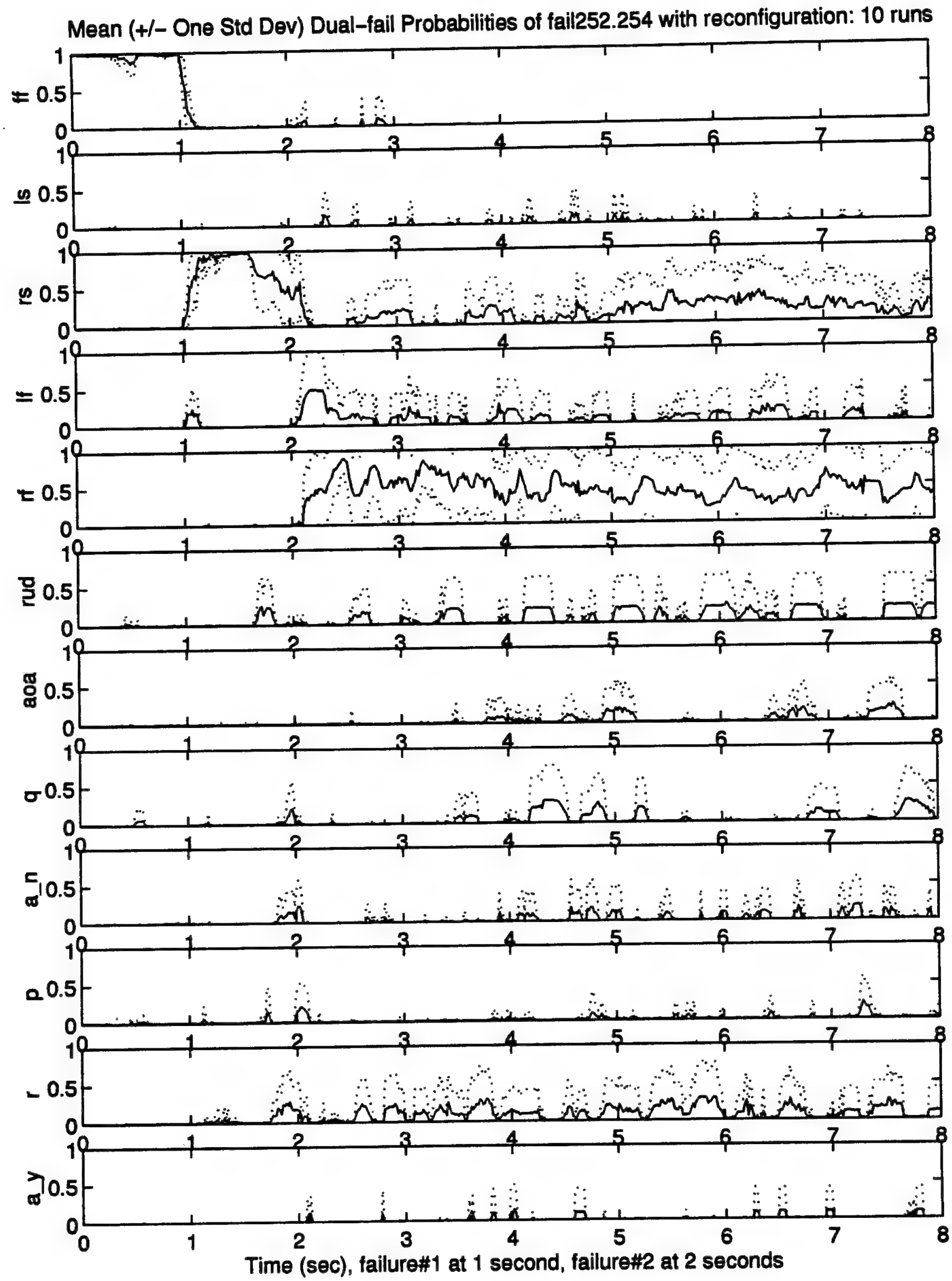
Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.250 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.251 with reconfiguration: 10 runs

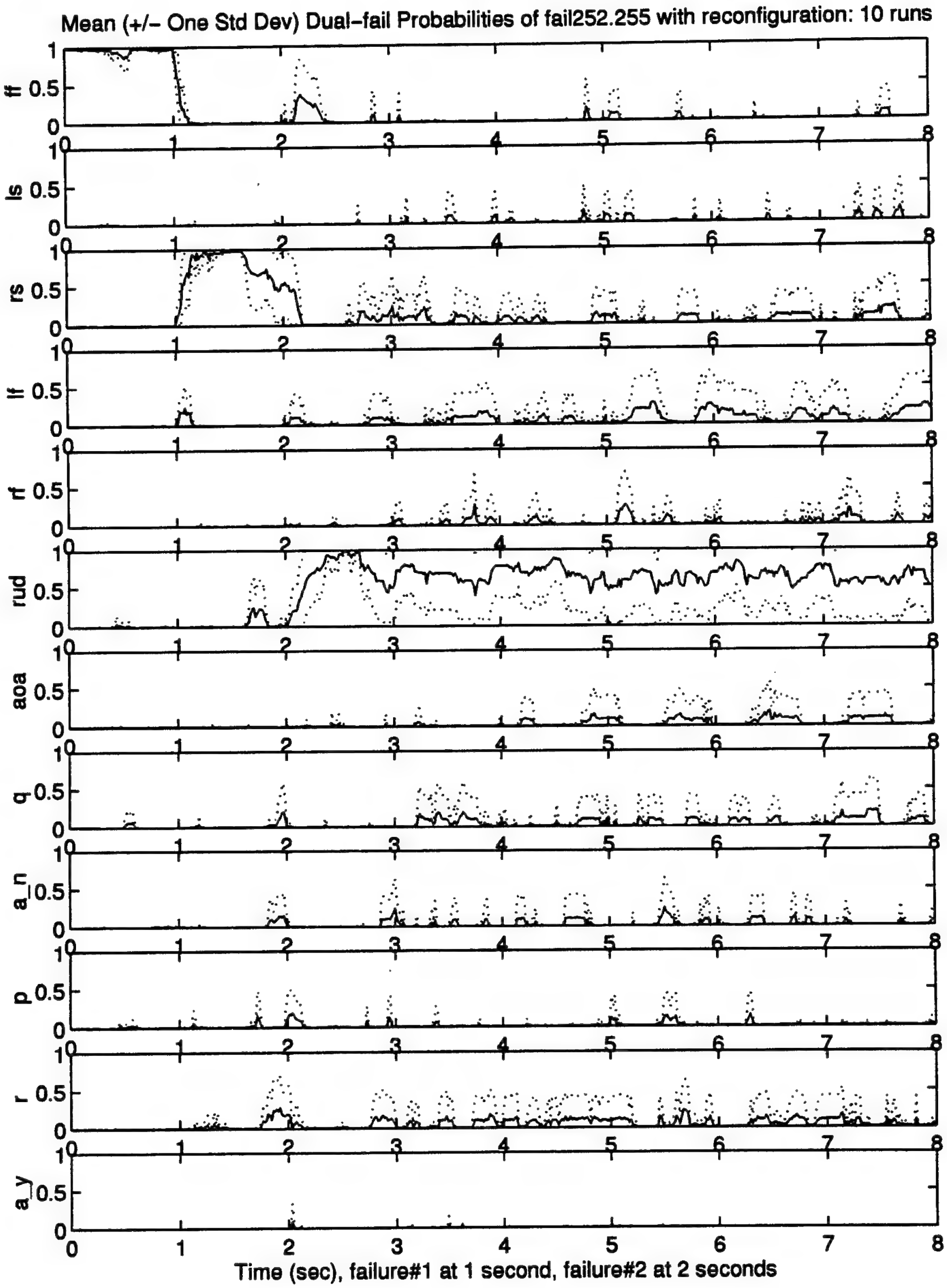




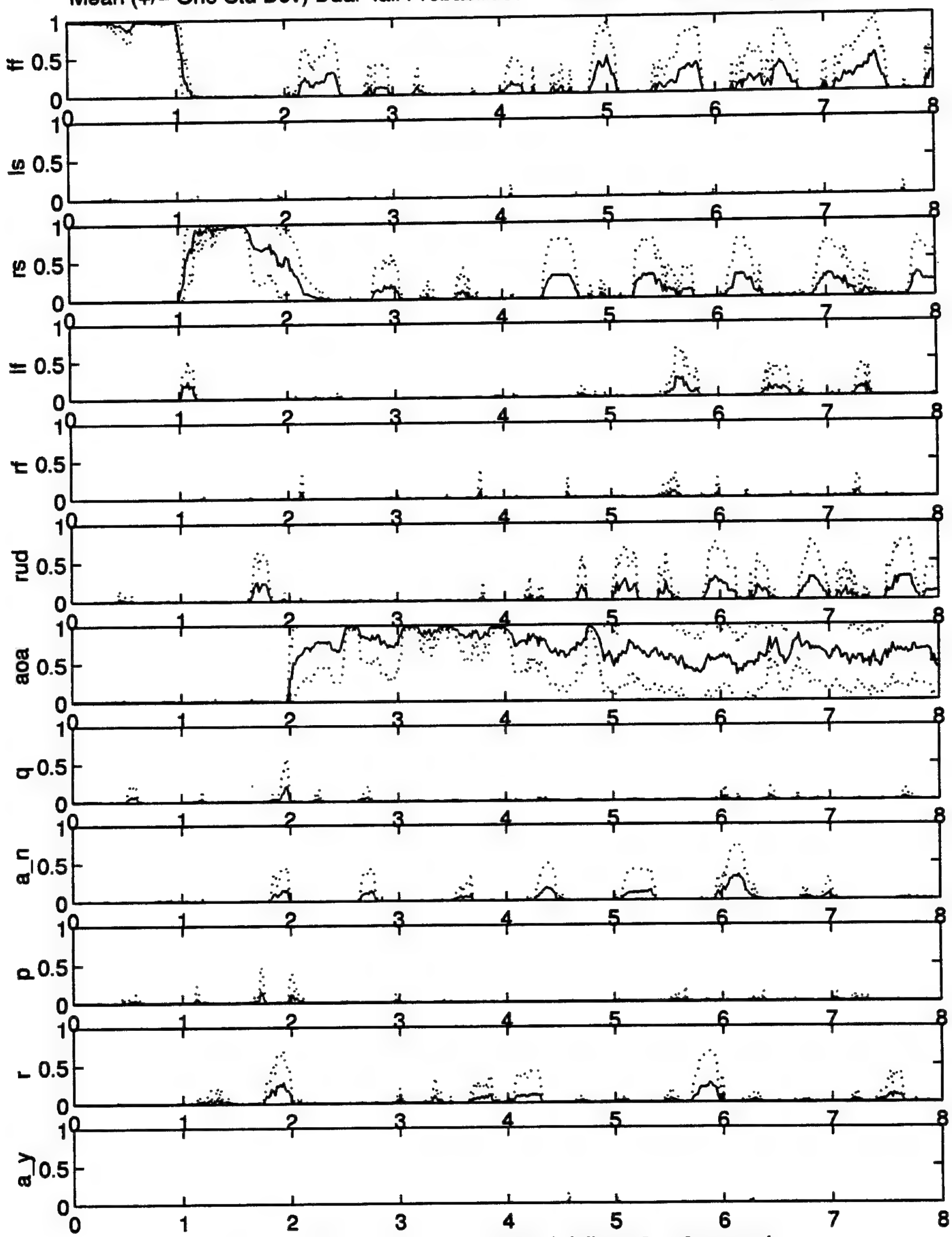
Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.253 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



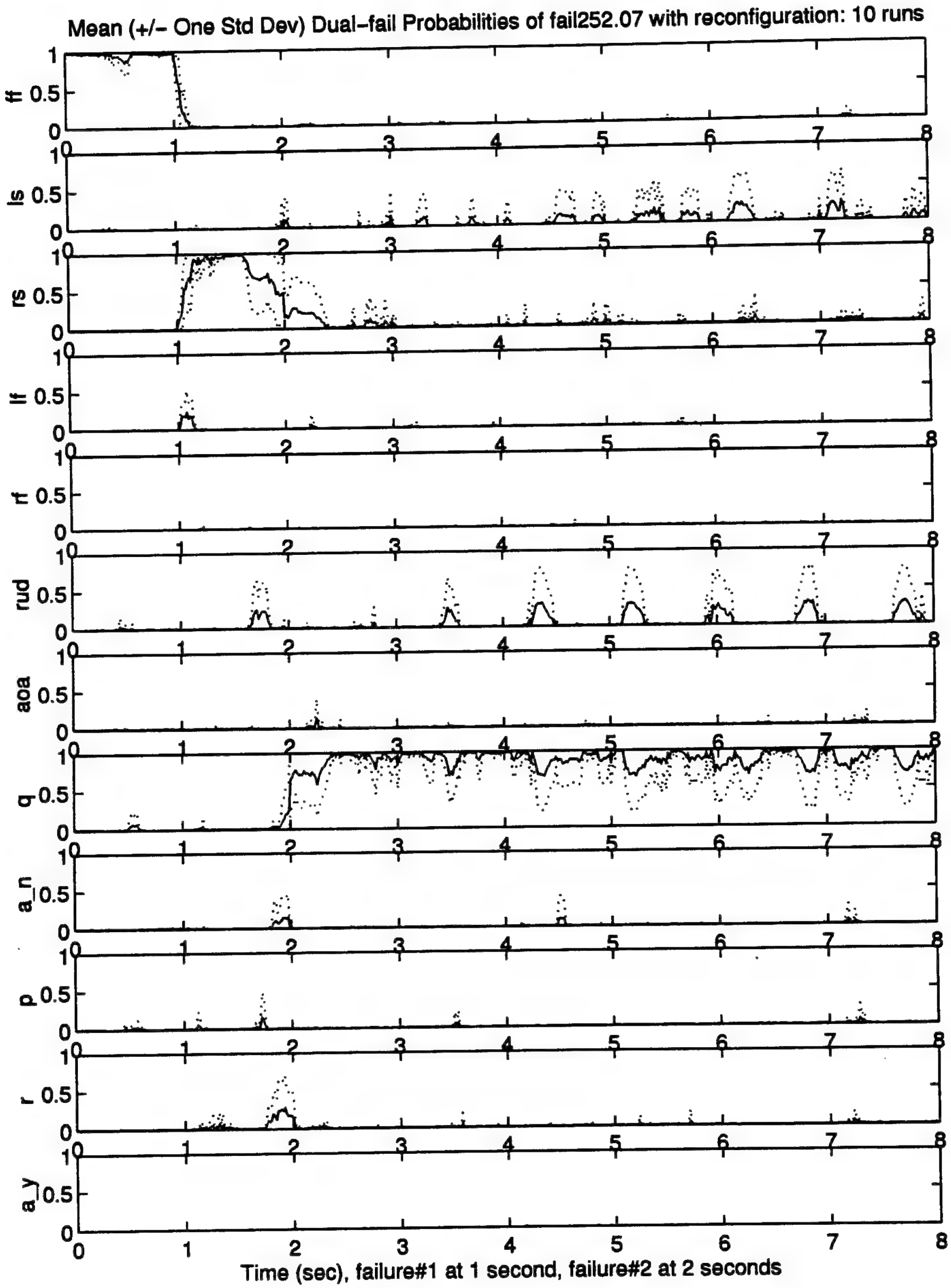
Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.254 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

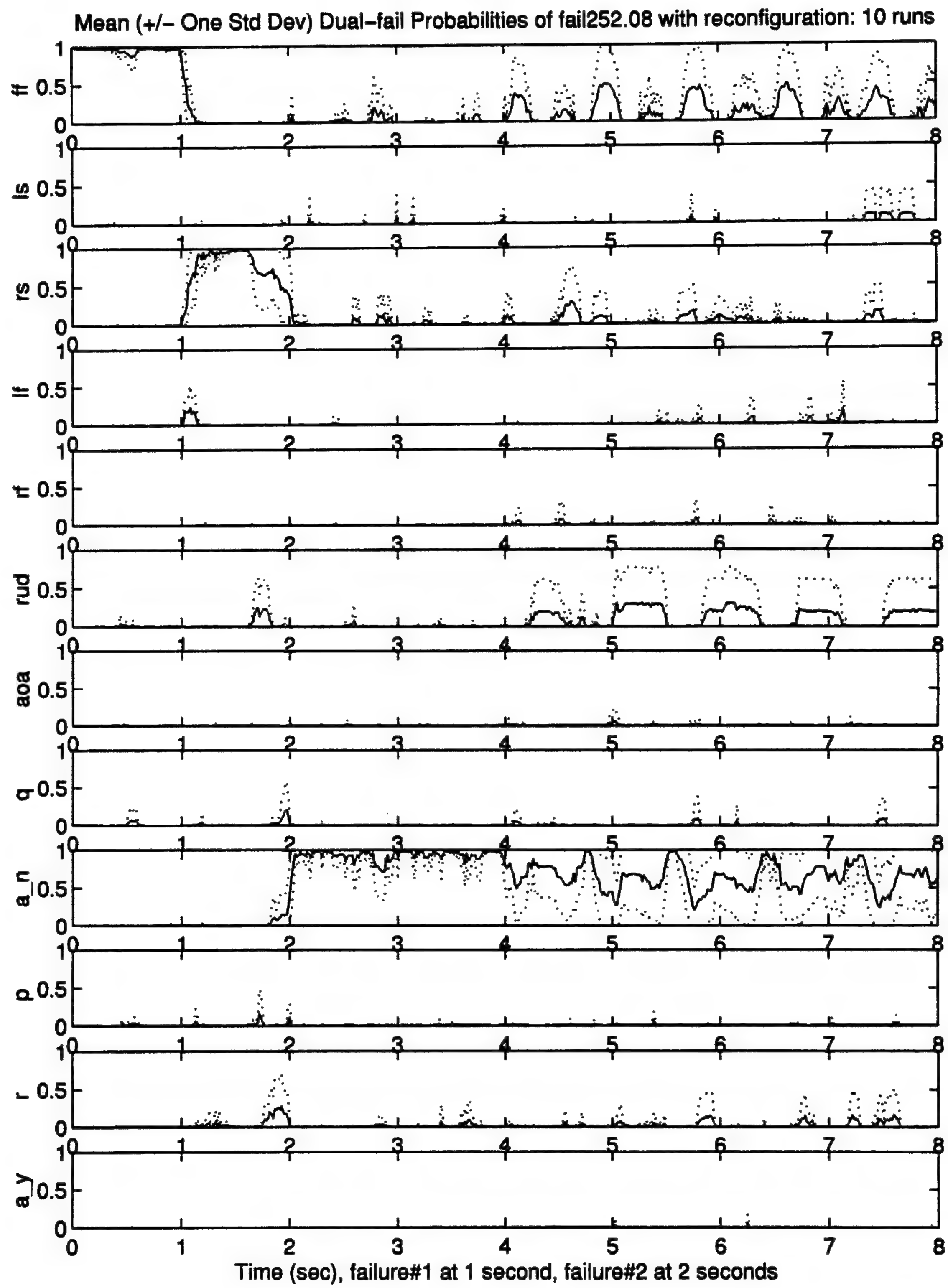

Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.255 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

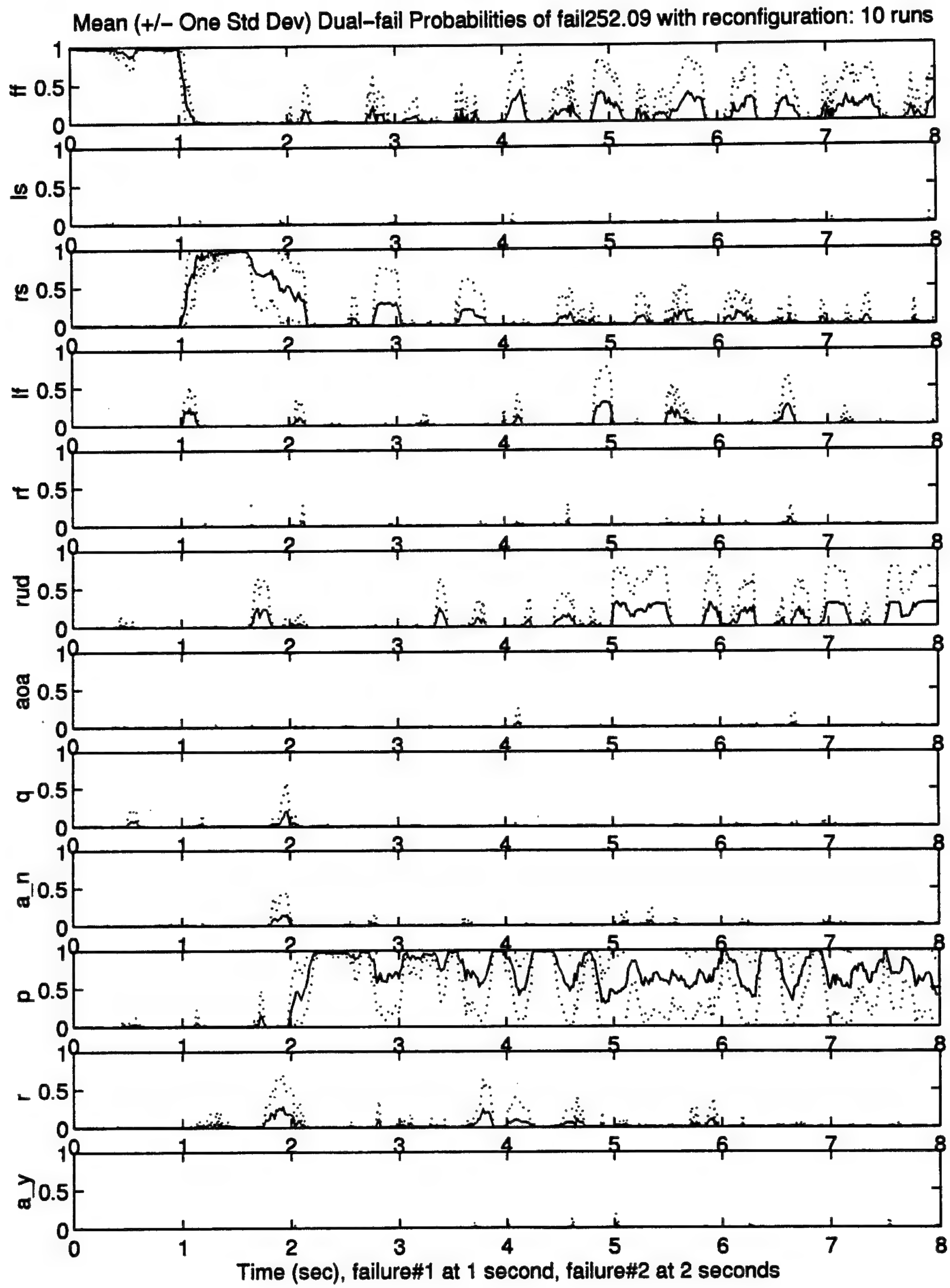
Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.06 with reconfiguration: 10 runs



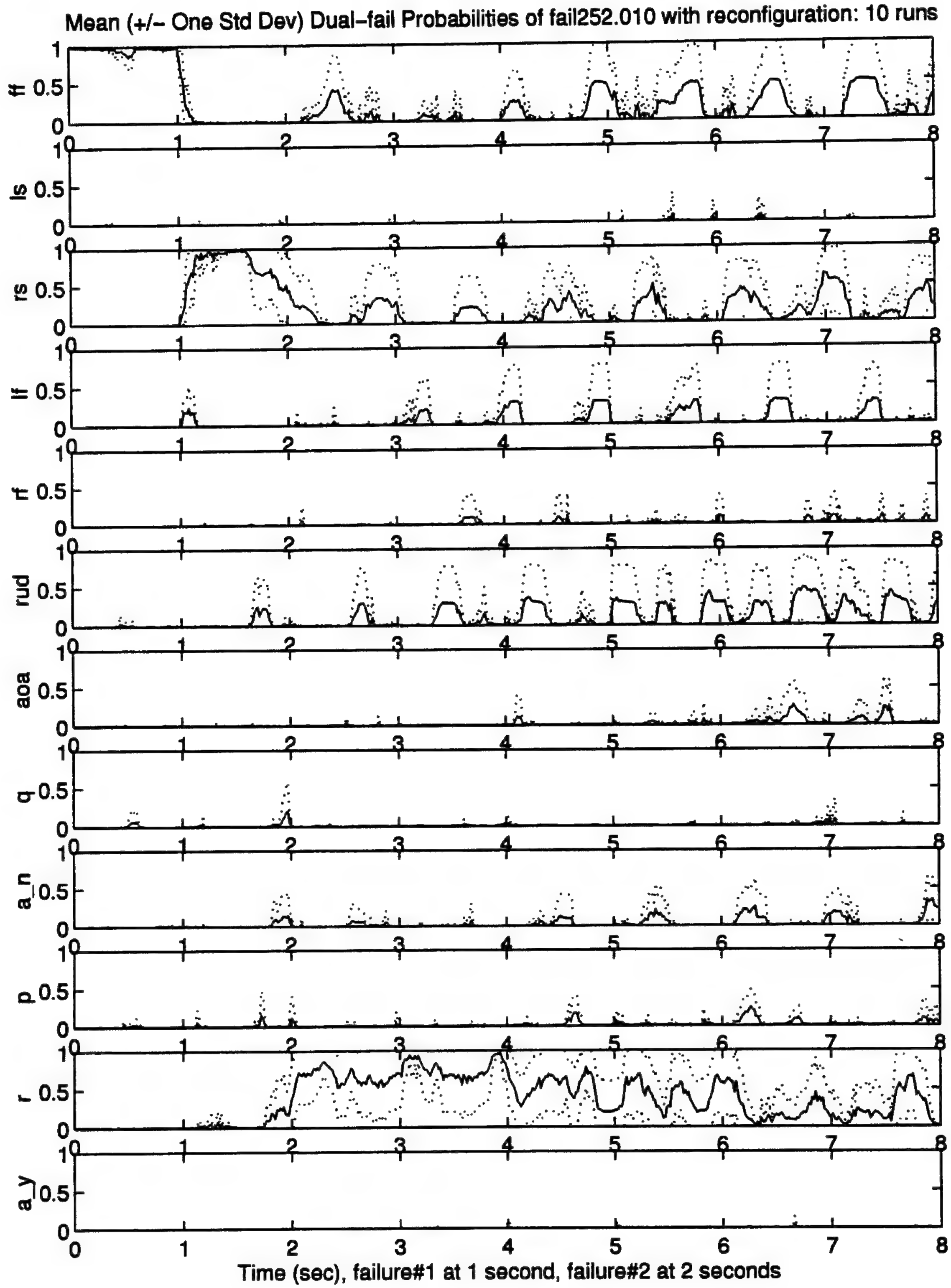
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

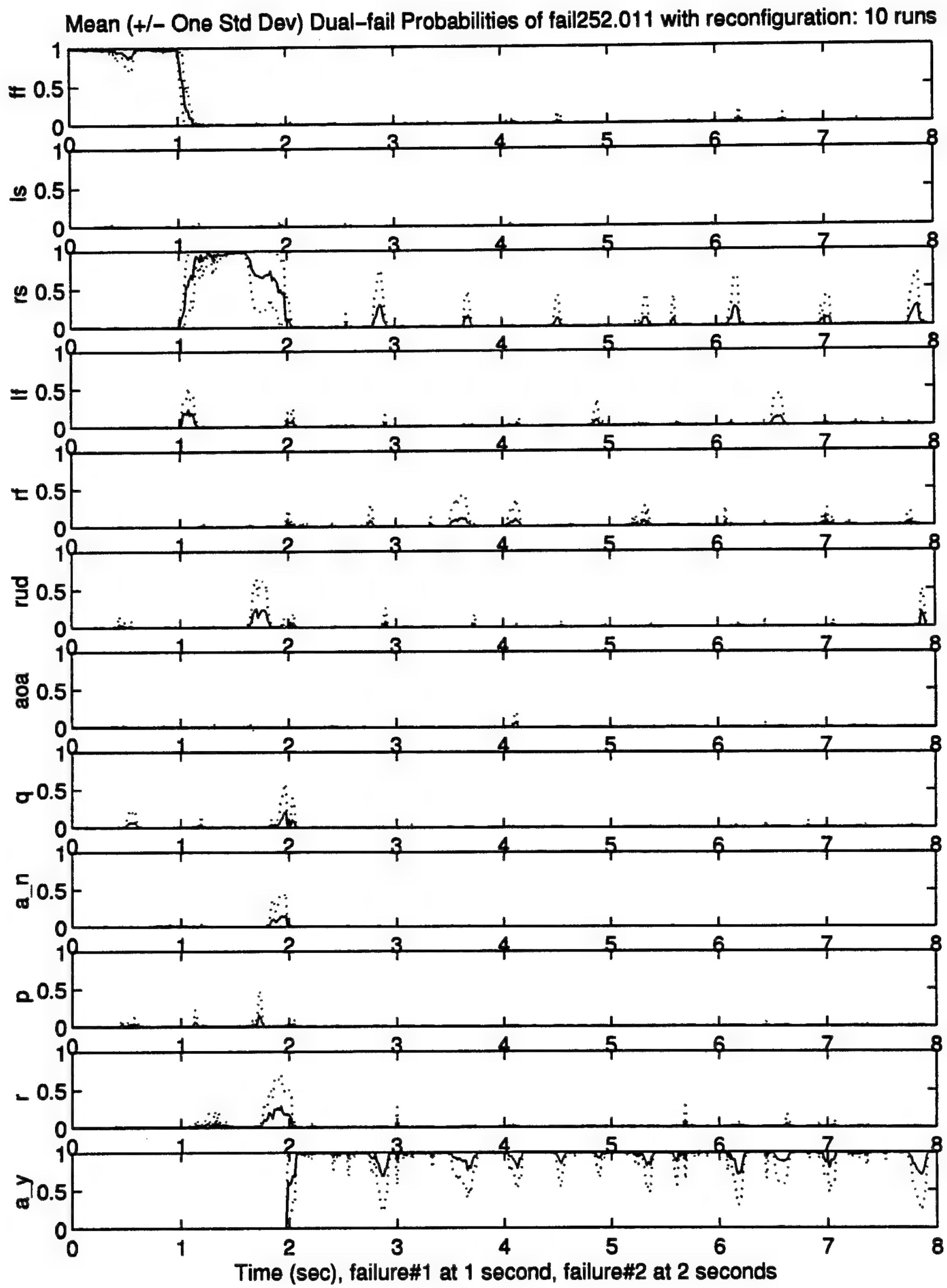

Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



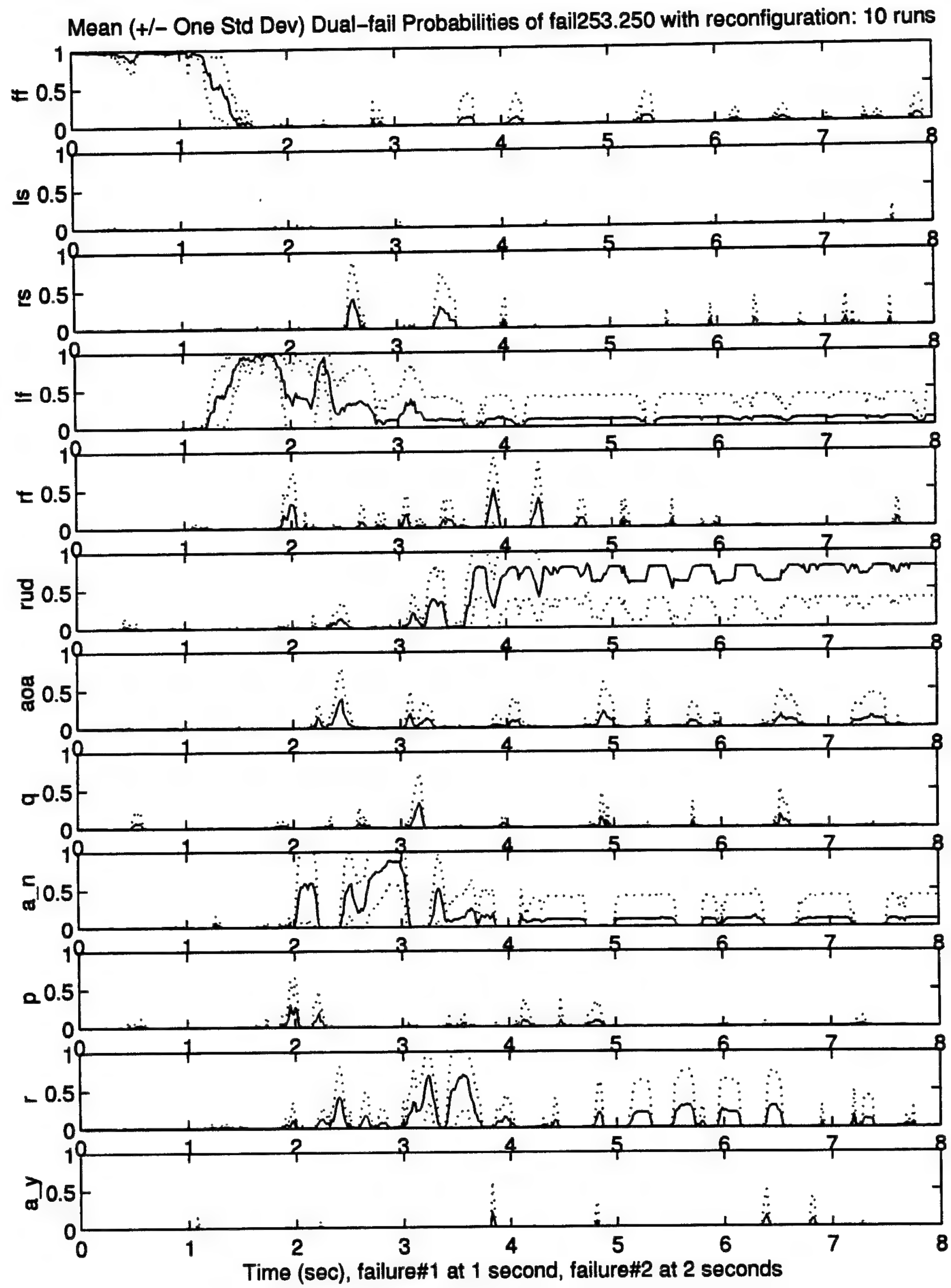
Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

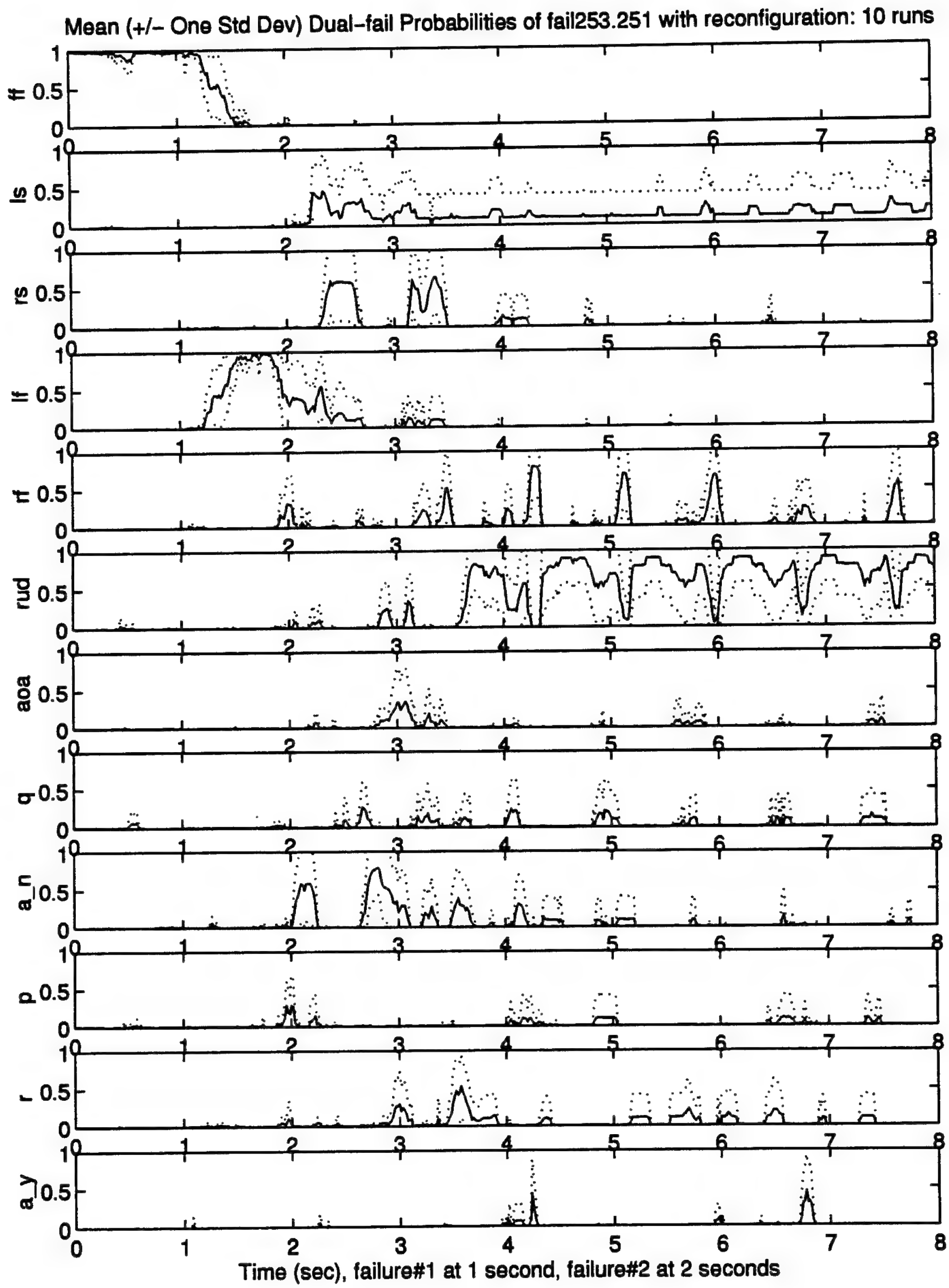


Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

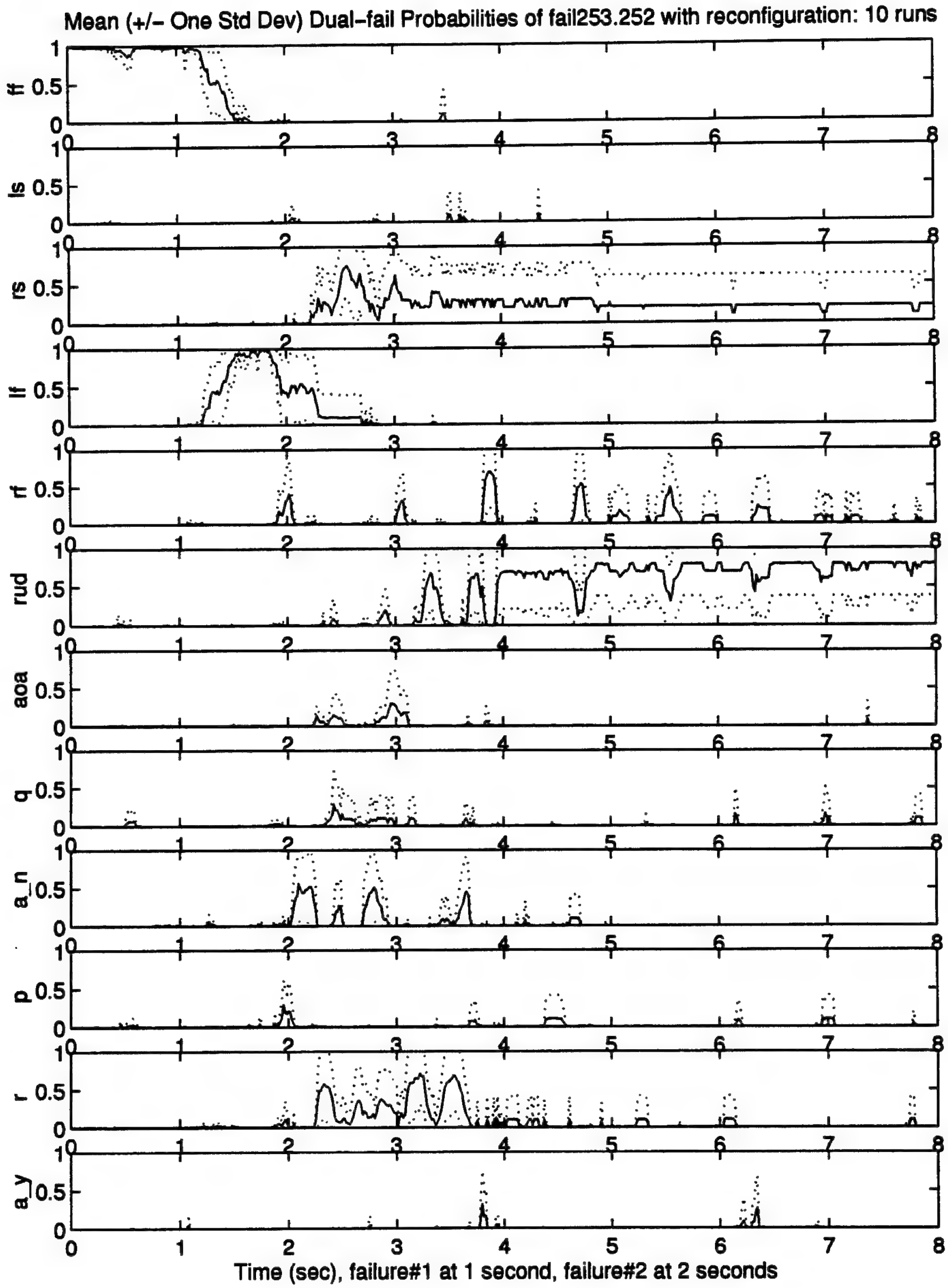


Mean (+/- One Std Dev) Dual-fail Probabilities of fail252.011 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

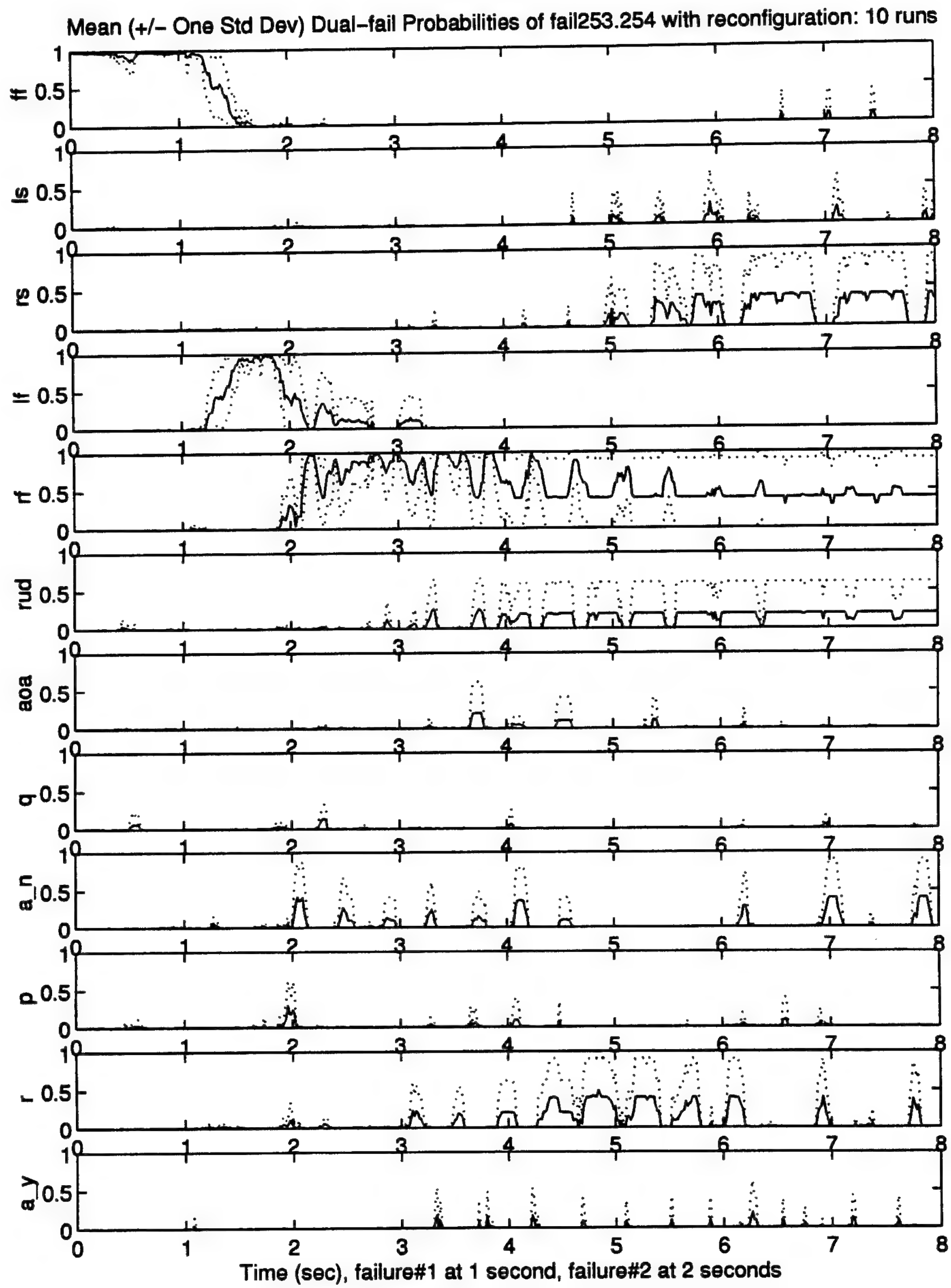

Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.250 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.251 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

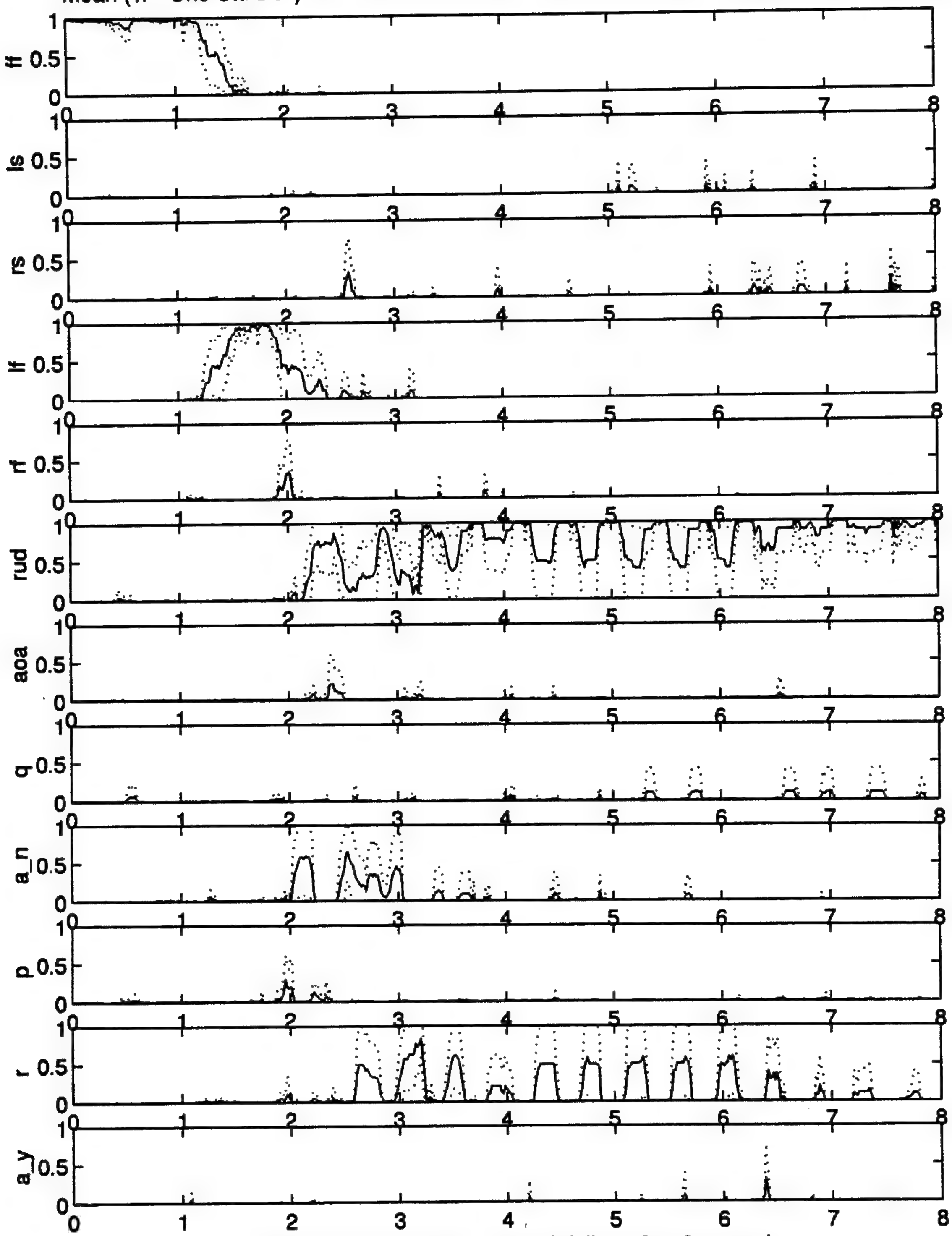


Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.252 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



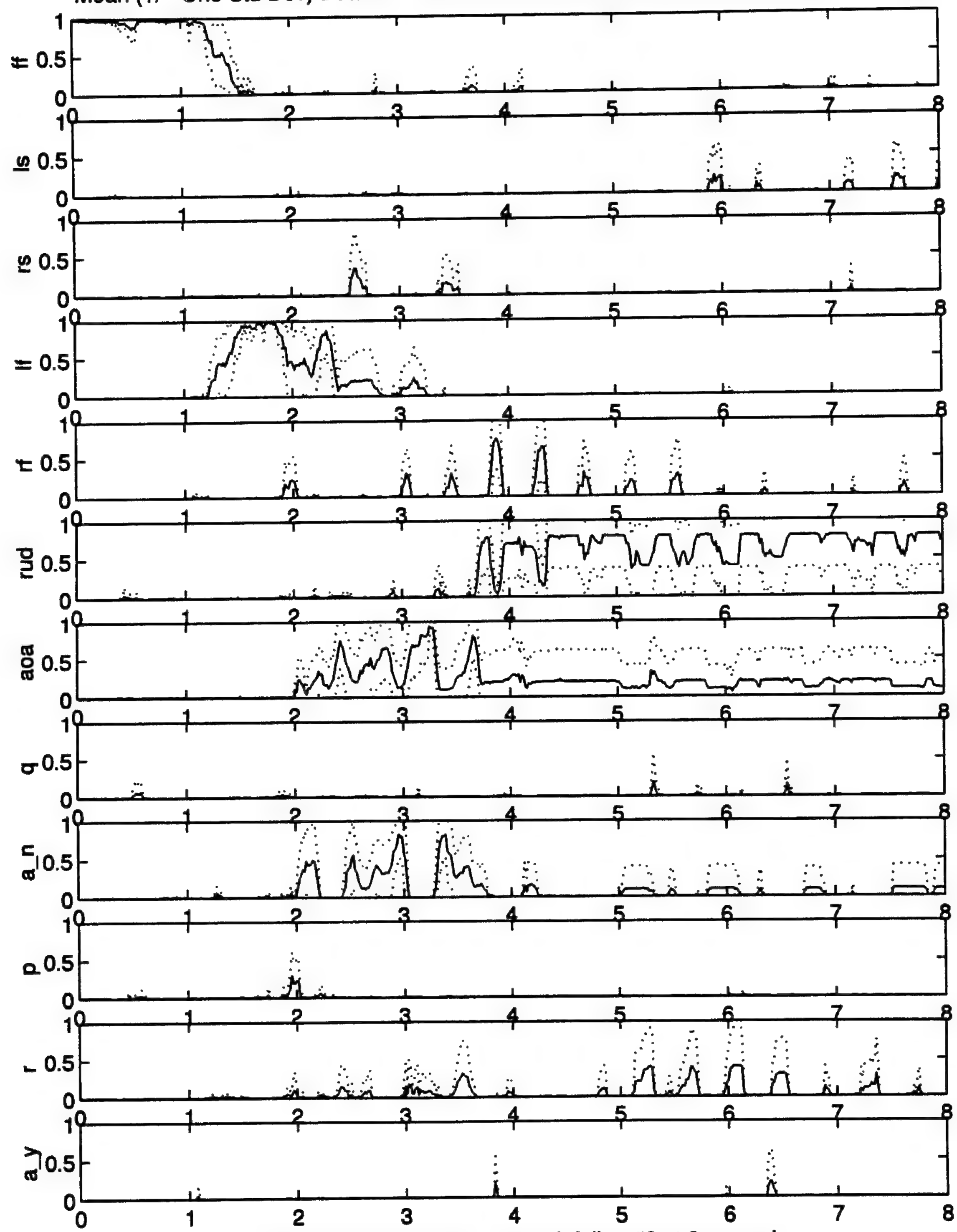
Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.254 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.255 with reconfiguration: 10 runs

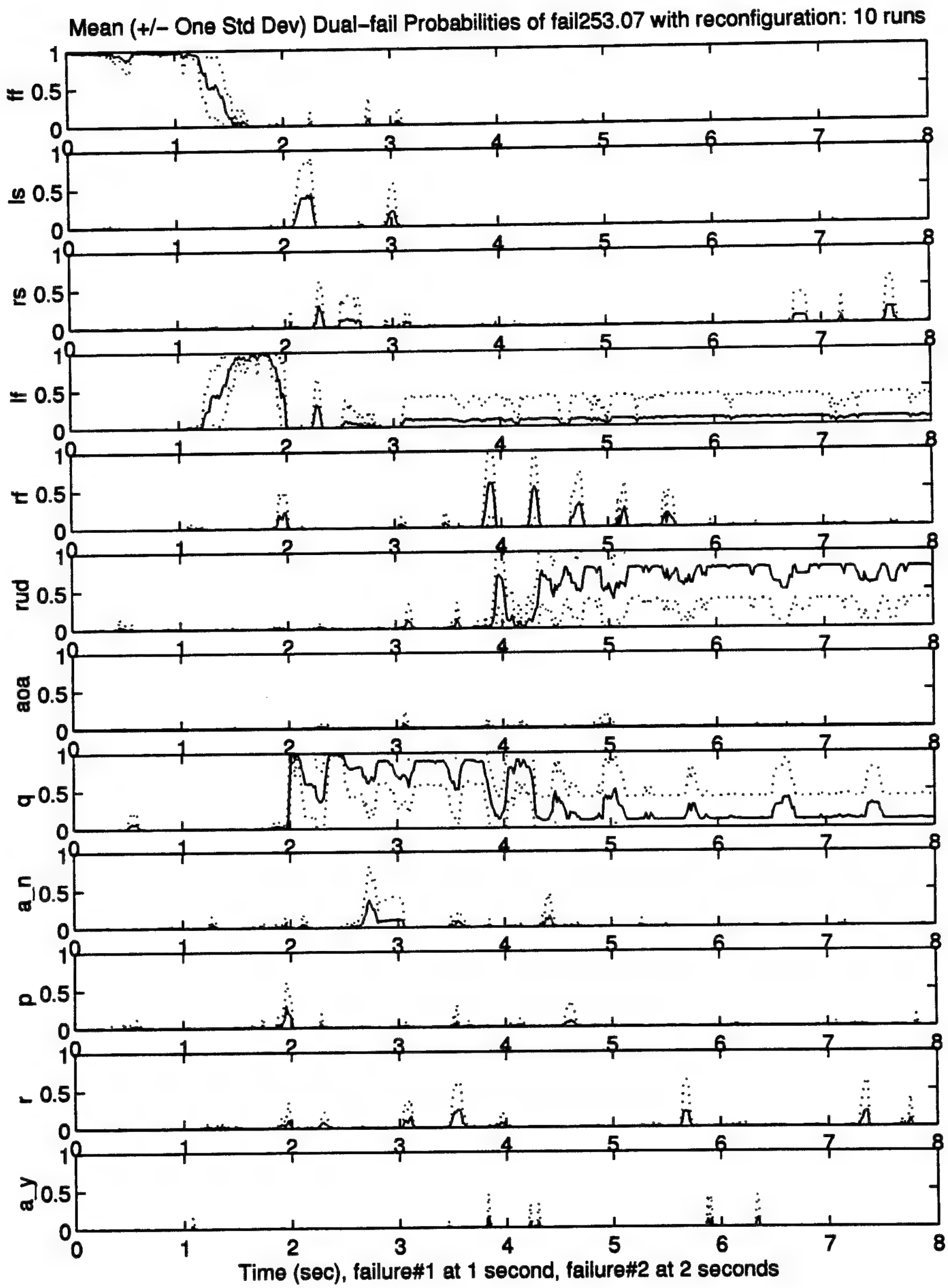


Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.06 with reconfiguration: 10 runs

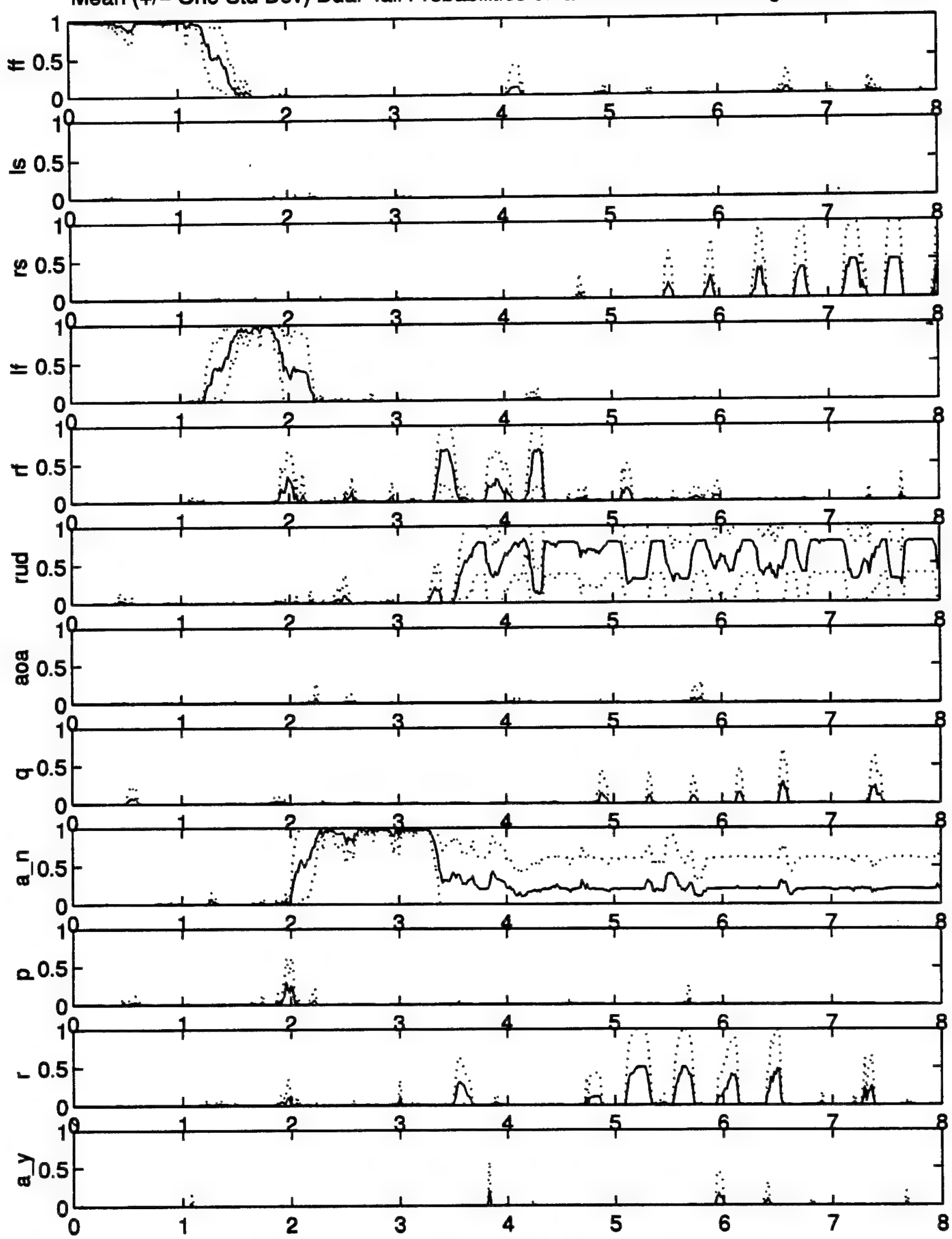


Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

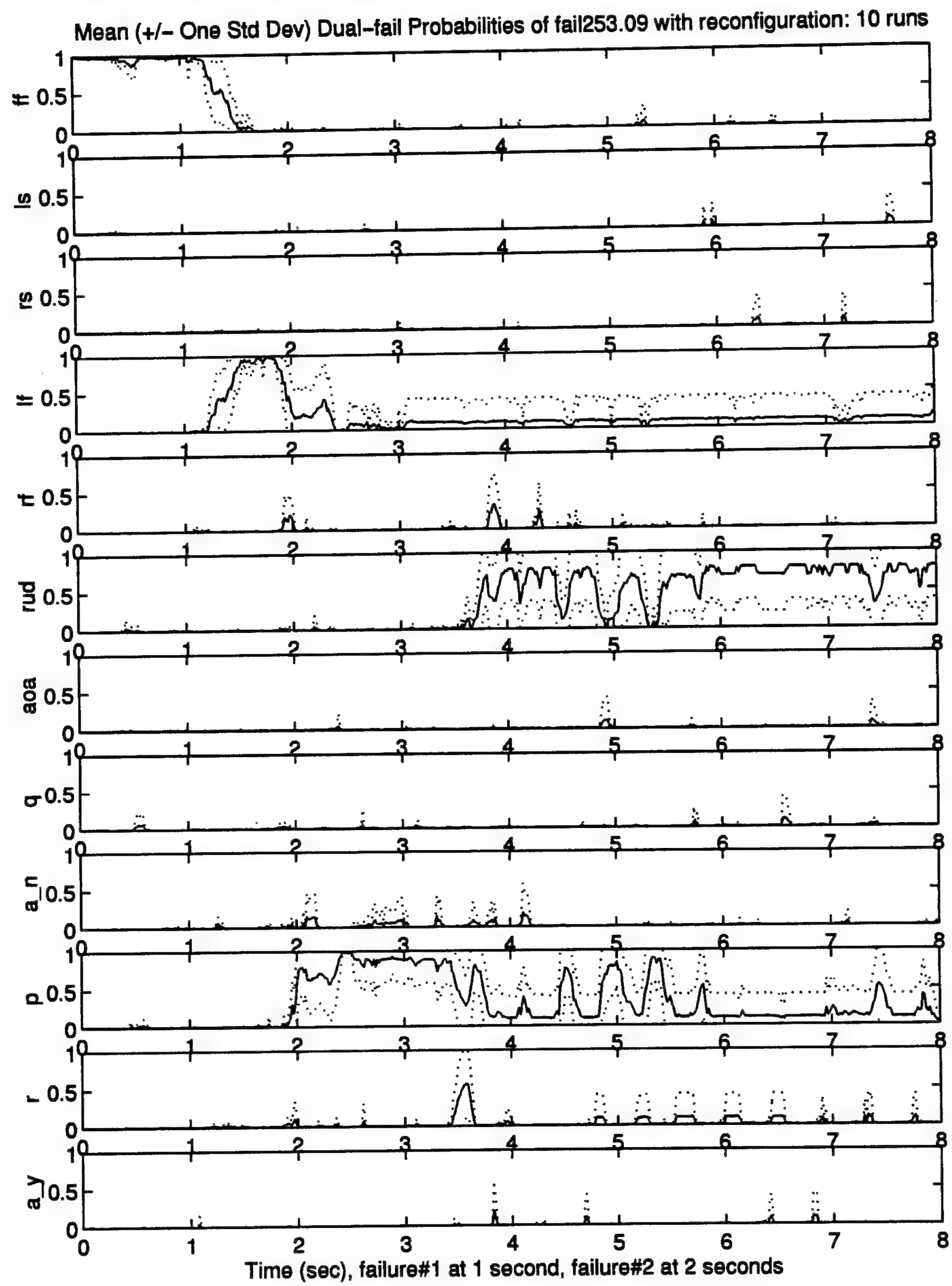


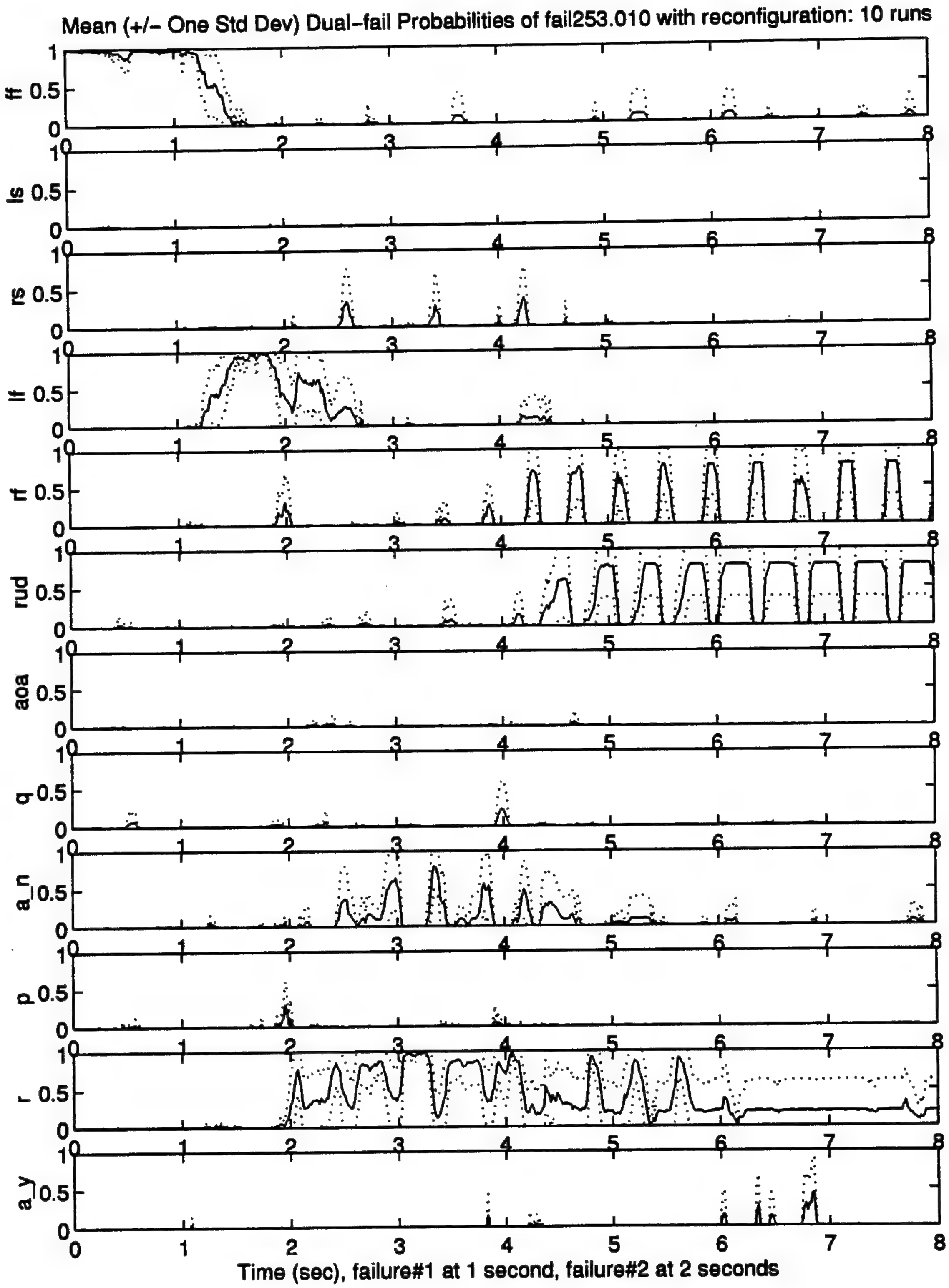
Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

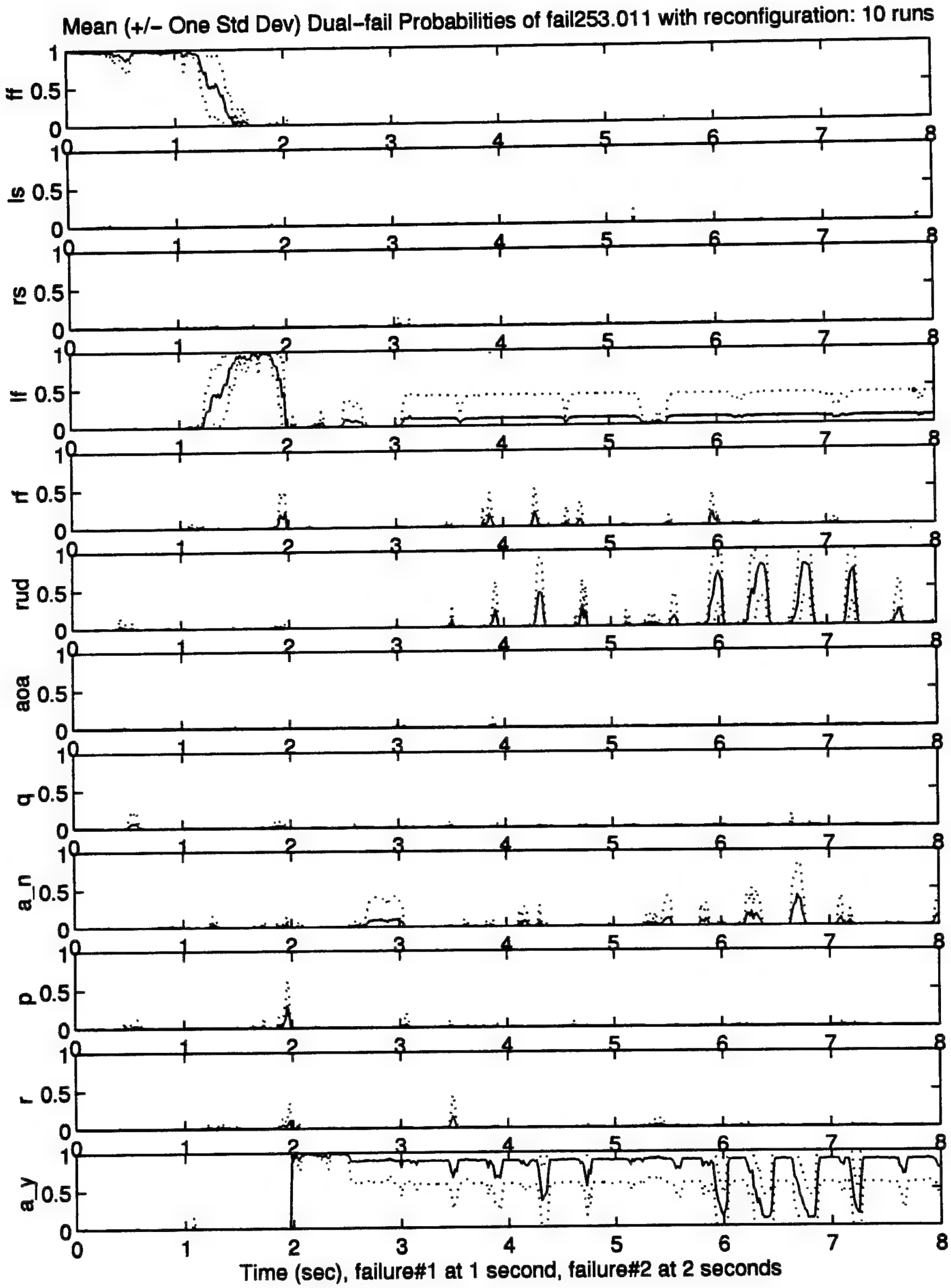
Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.08 with reconfiguration: 10 runs



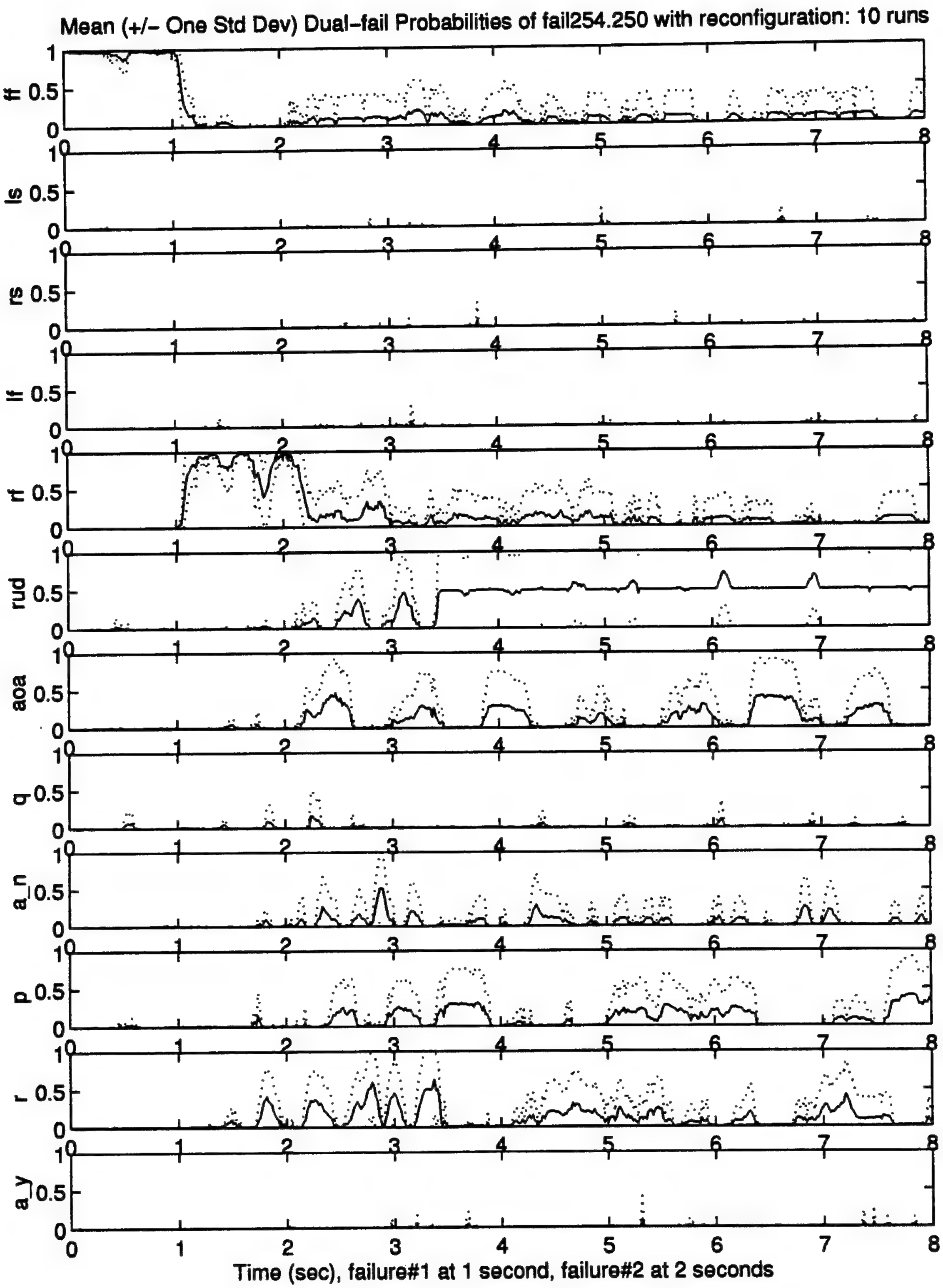
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

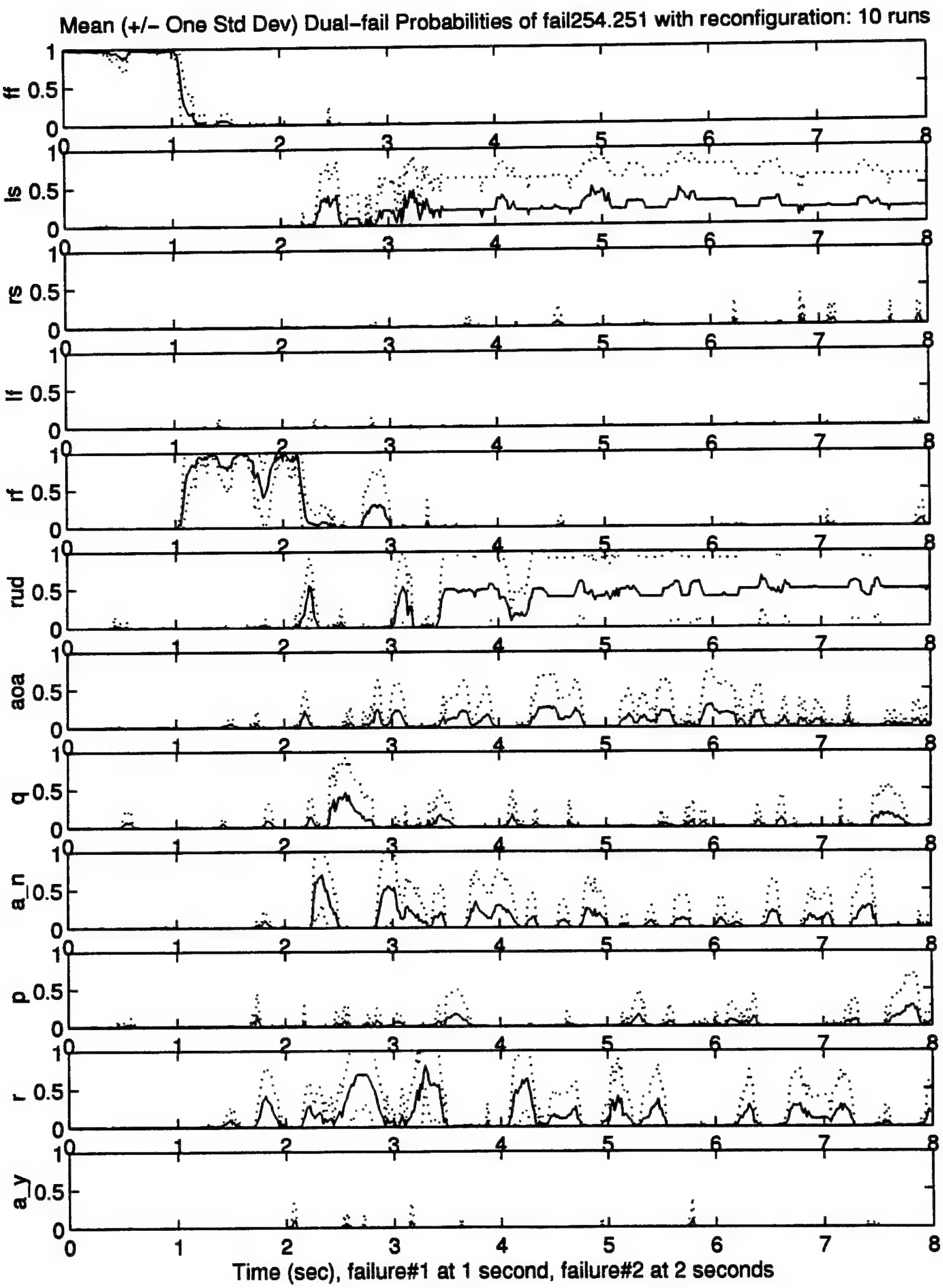

Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

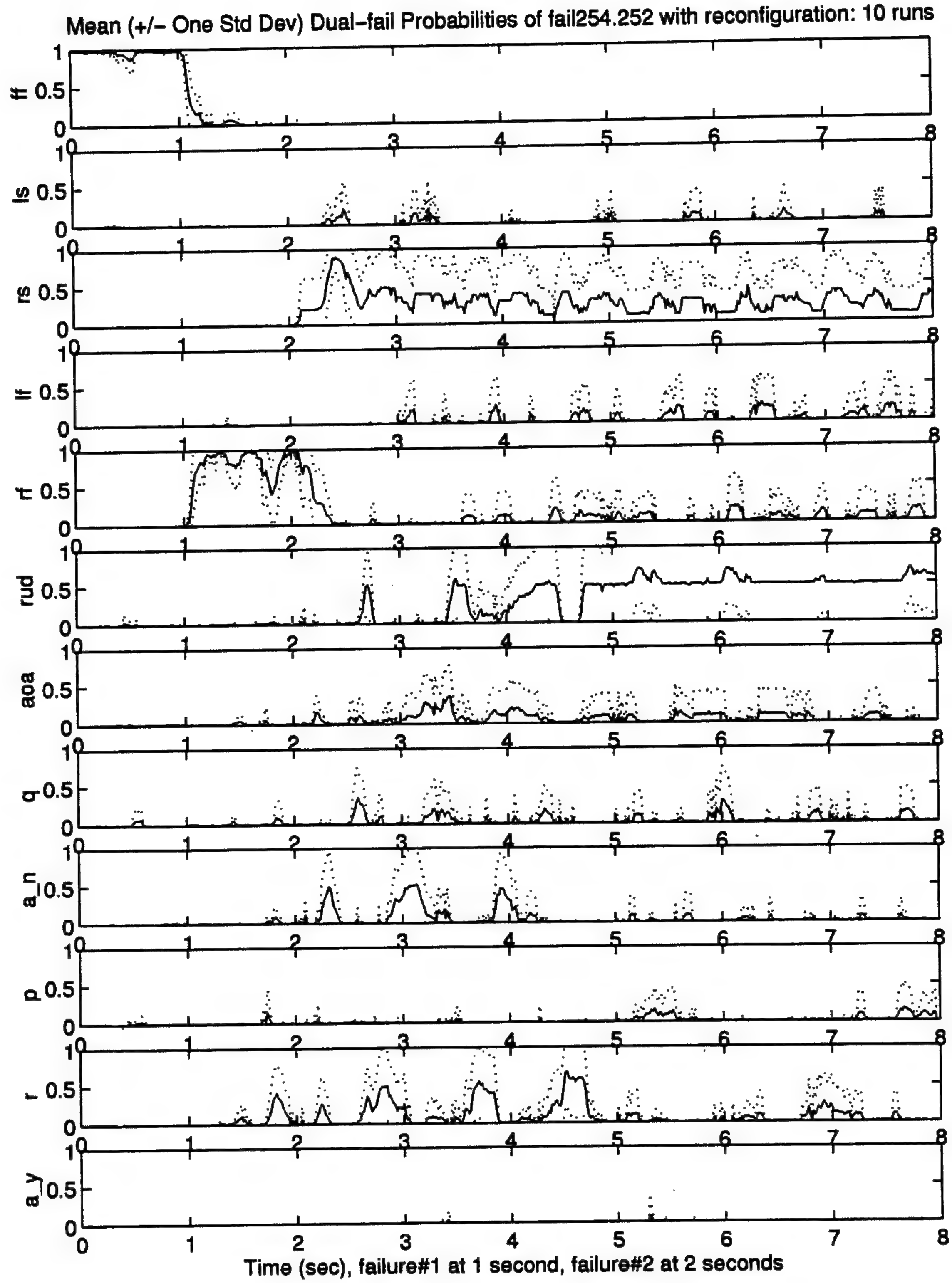


Mean (+/- One Std Dev) Dual-fail Probabilities of fail253.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

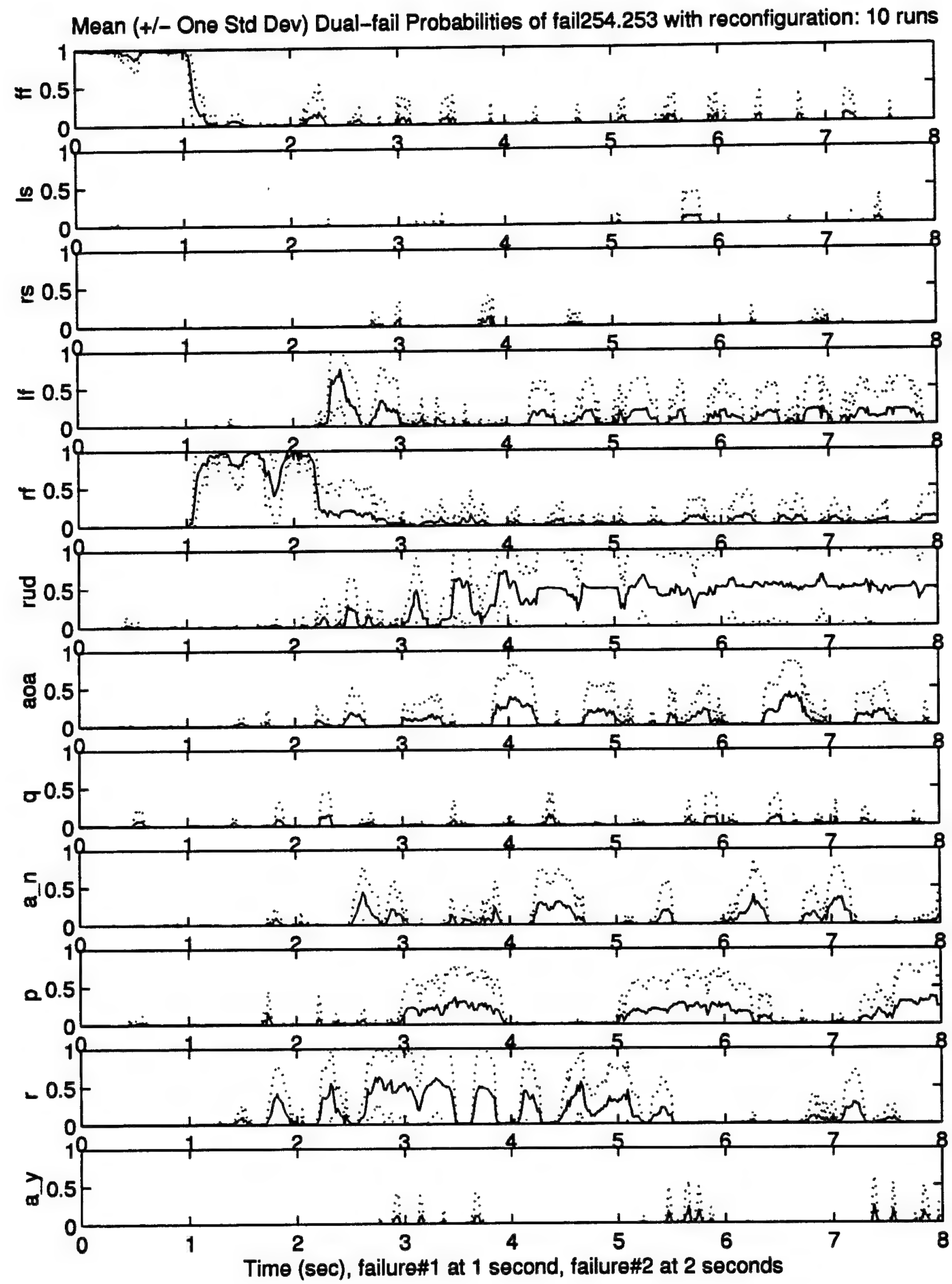


Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.250 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

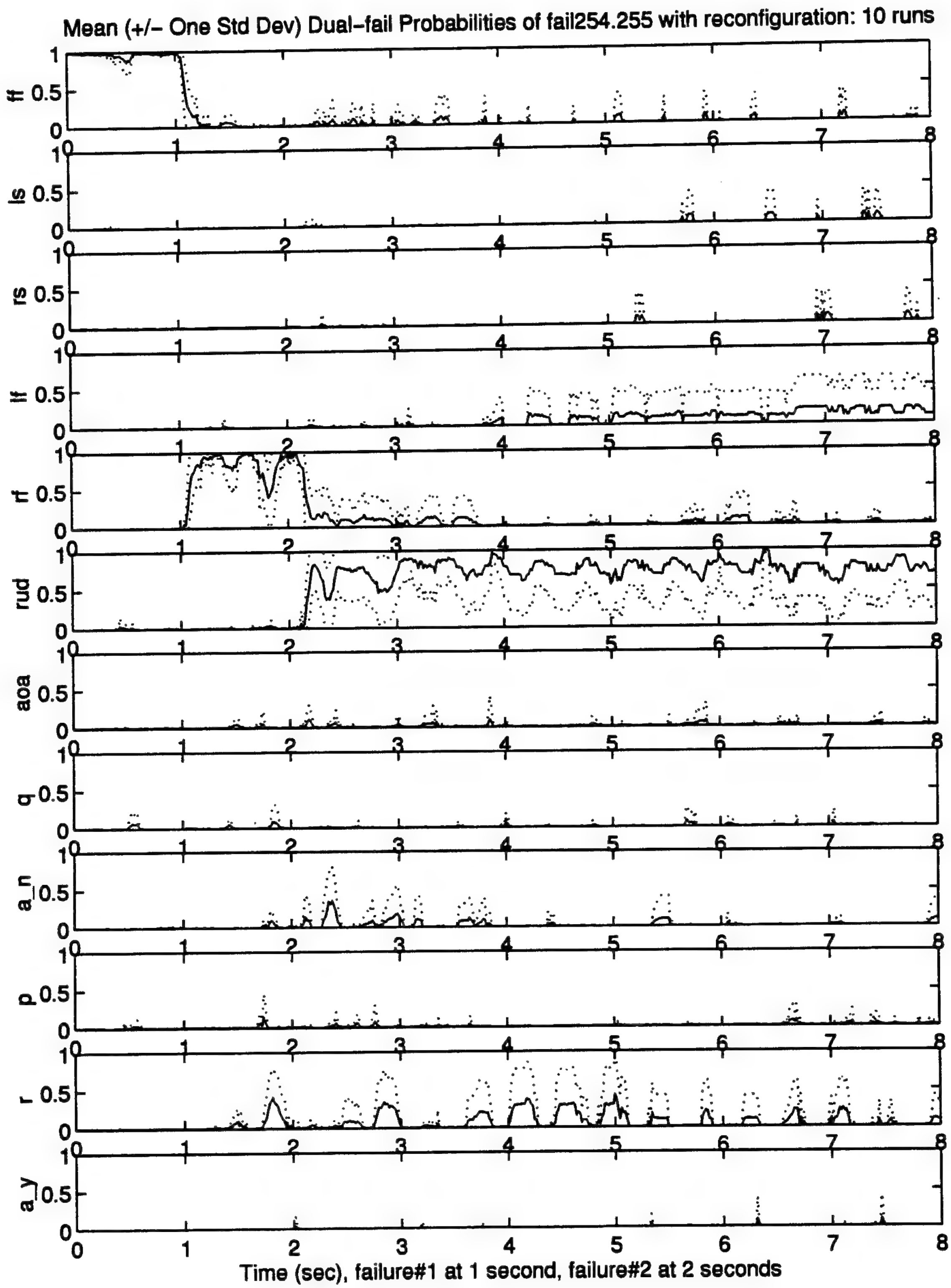

Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.251 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



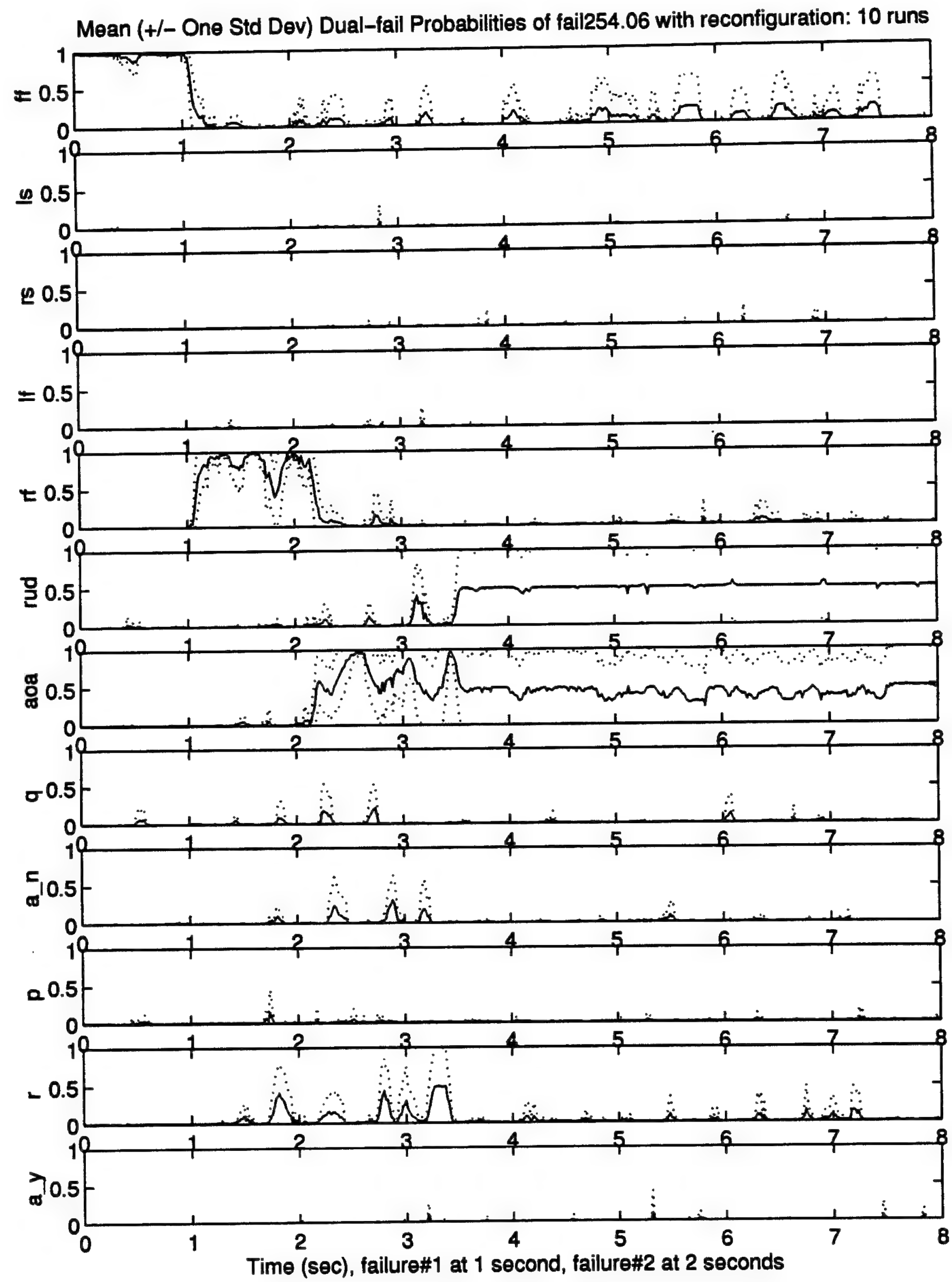
Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.252 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



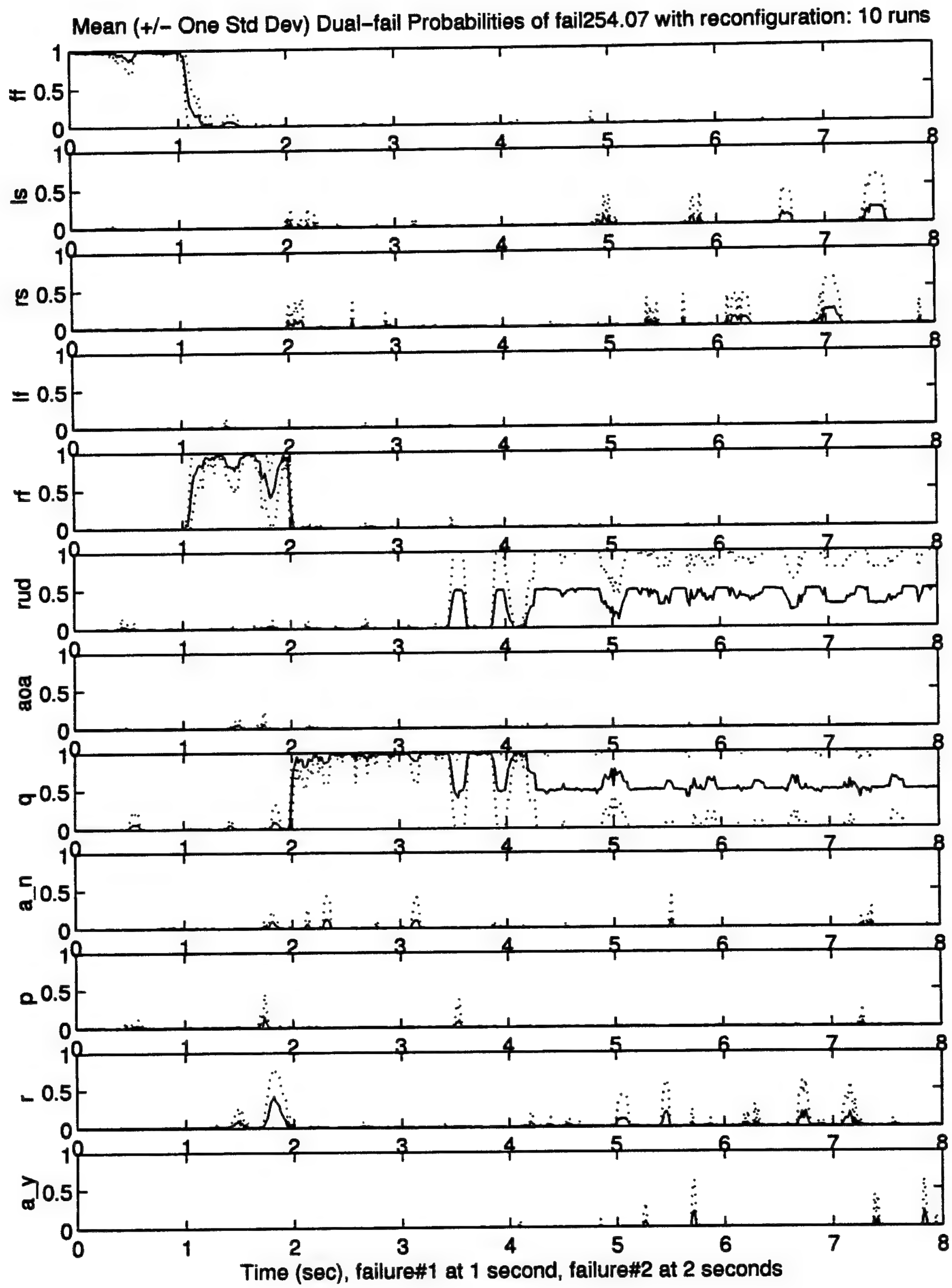
Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.253 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



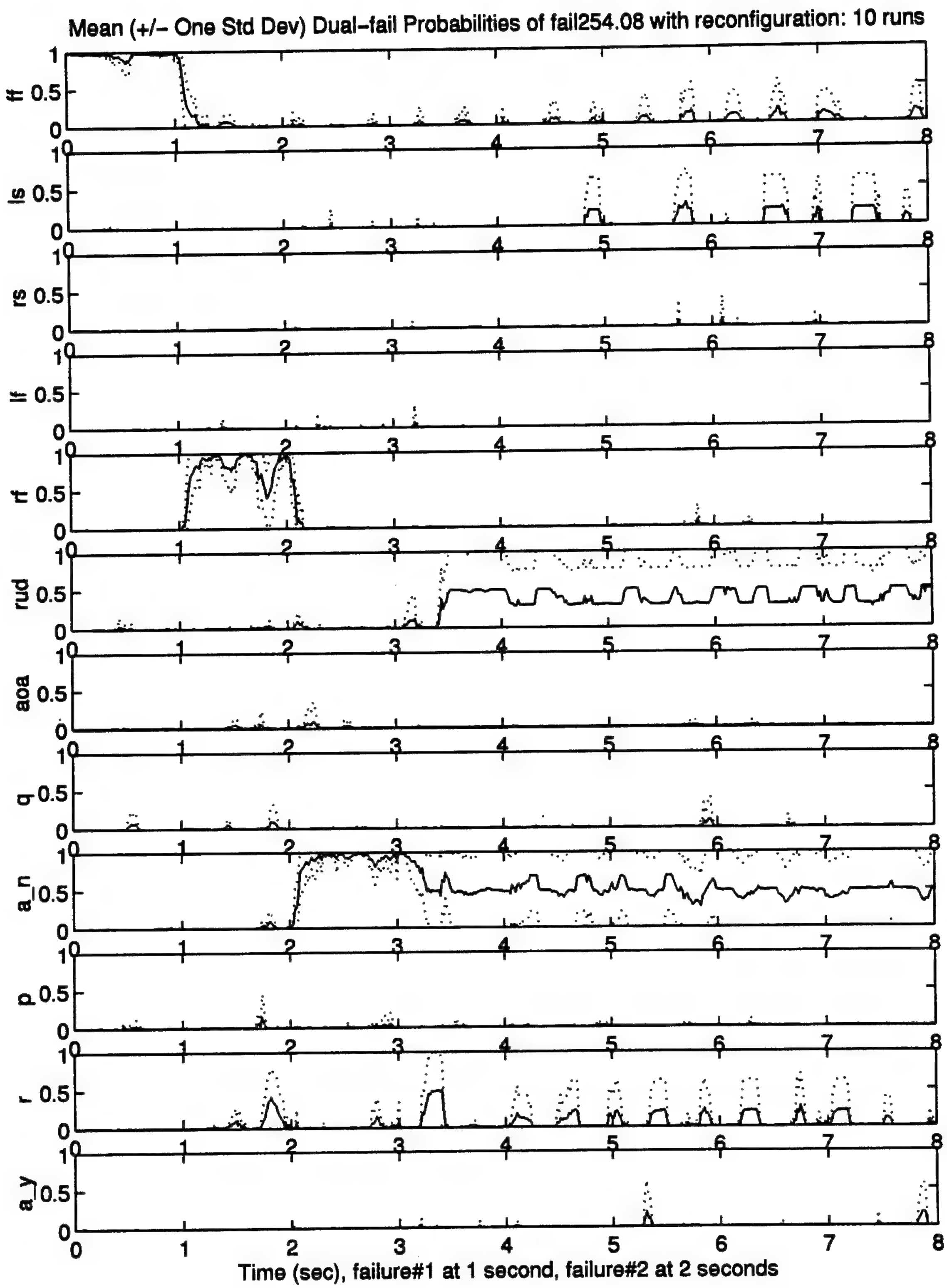
Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.255 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

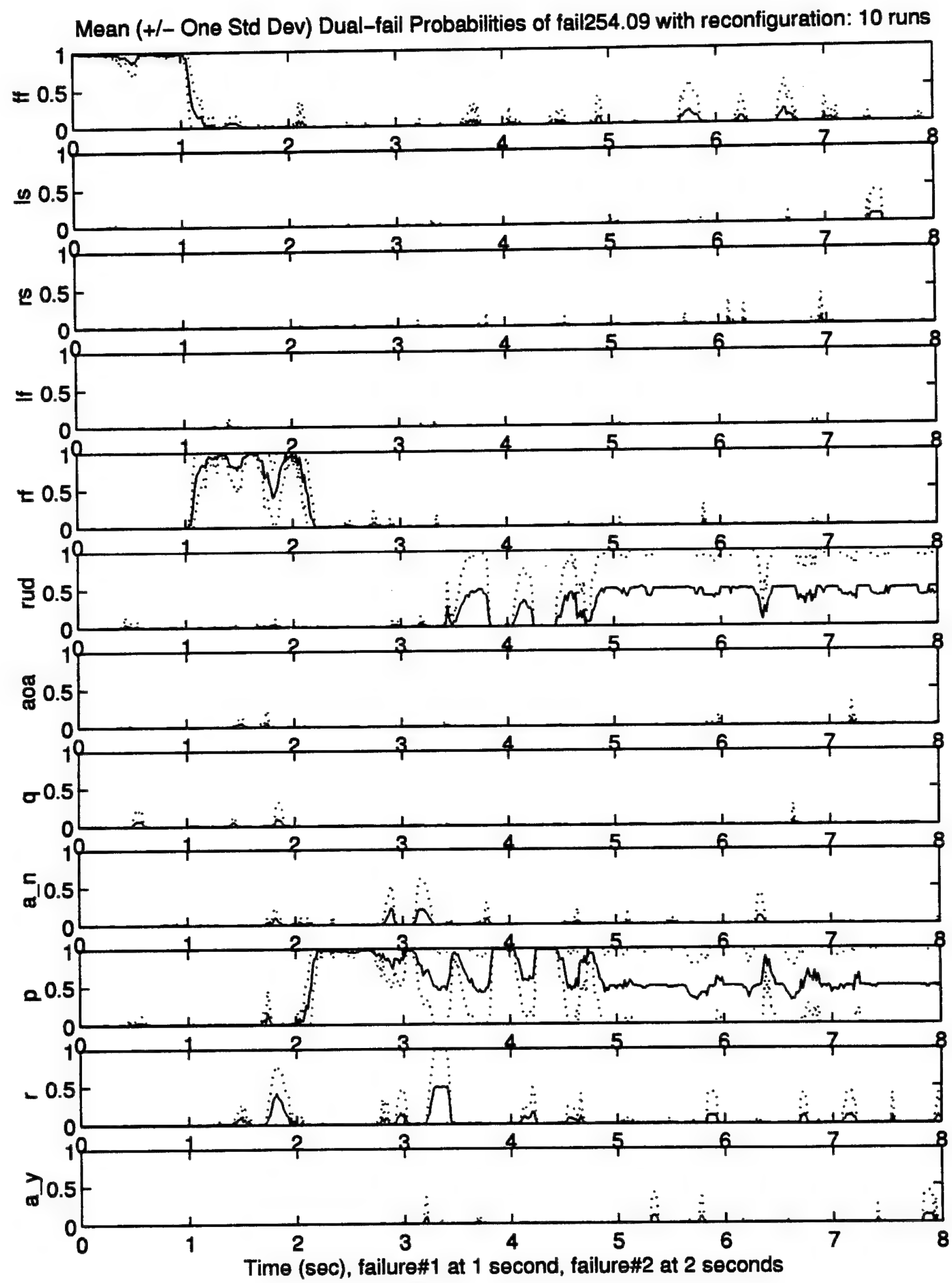


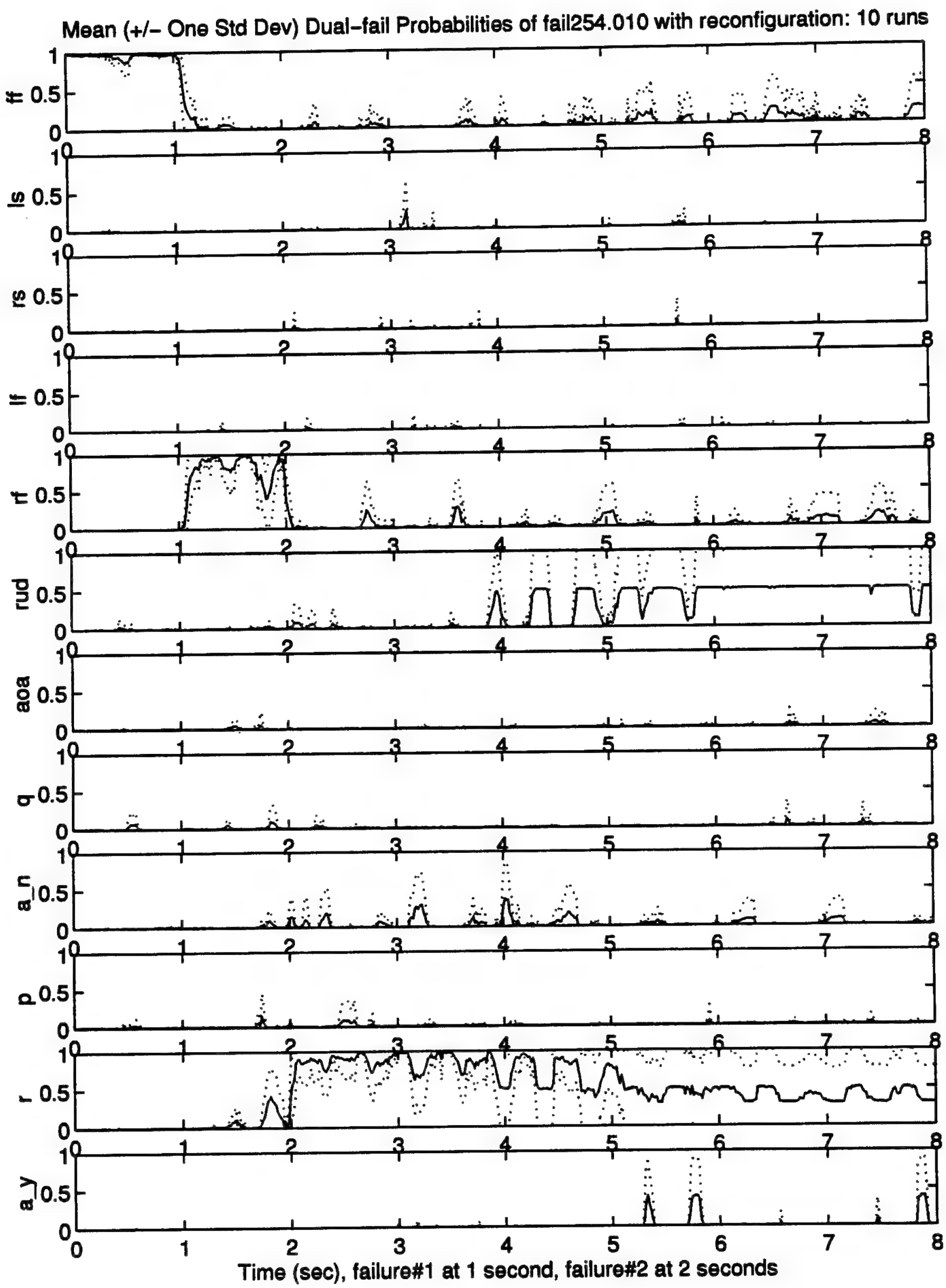
Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.06 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

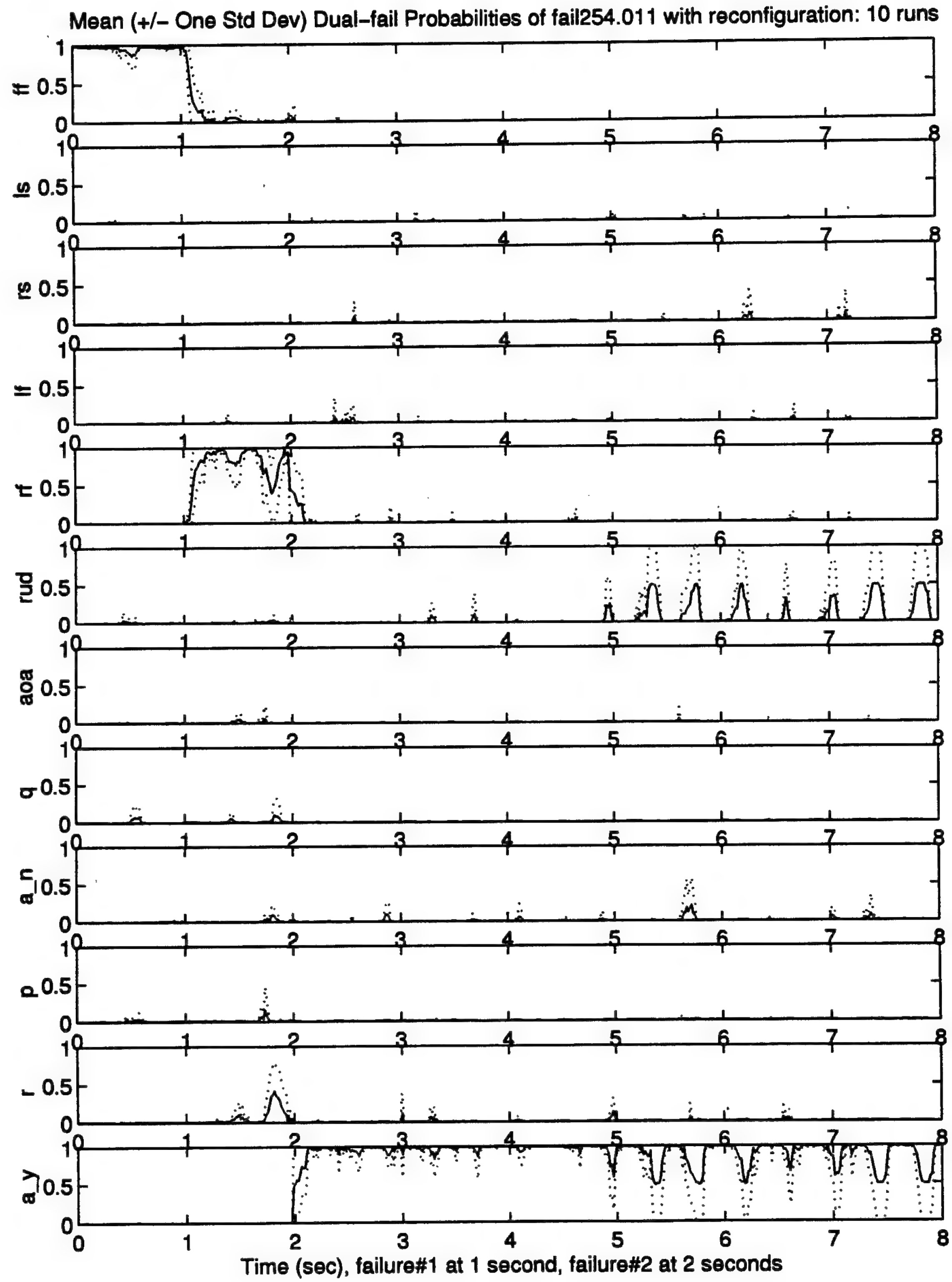


Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

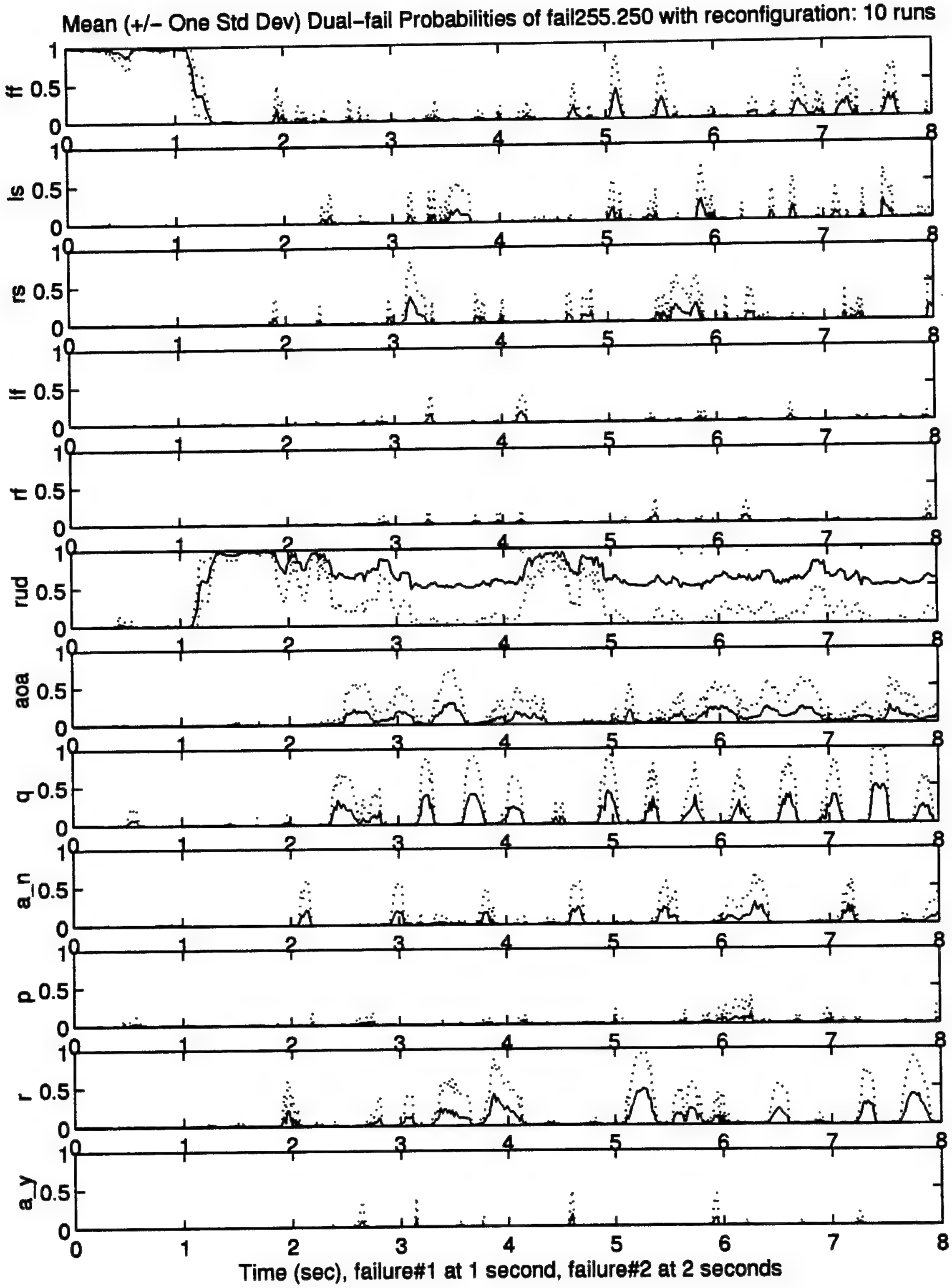

Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

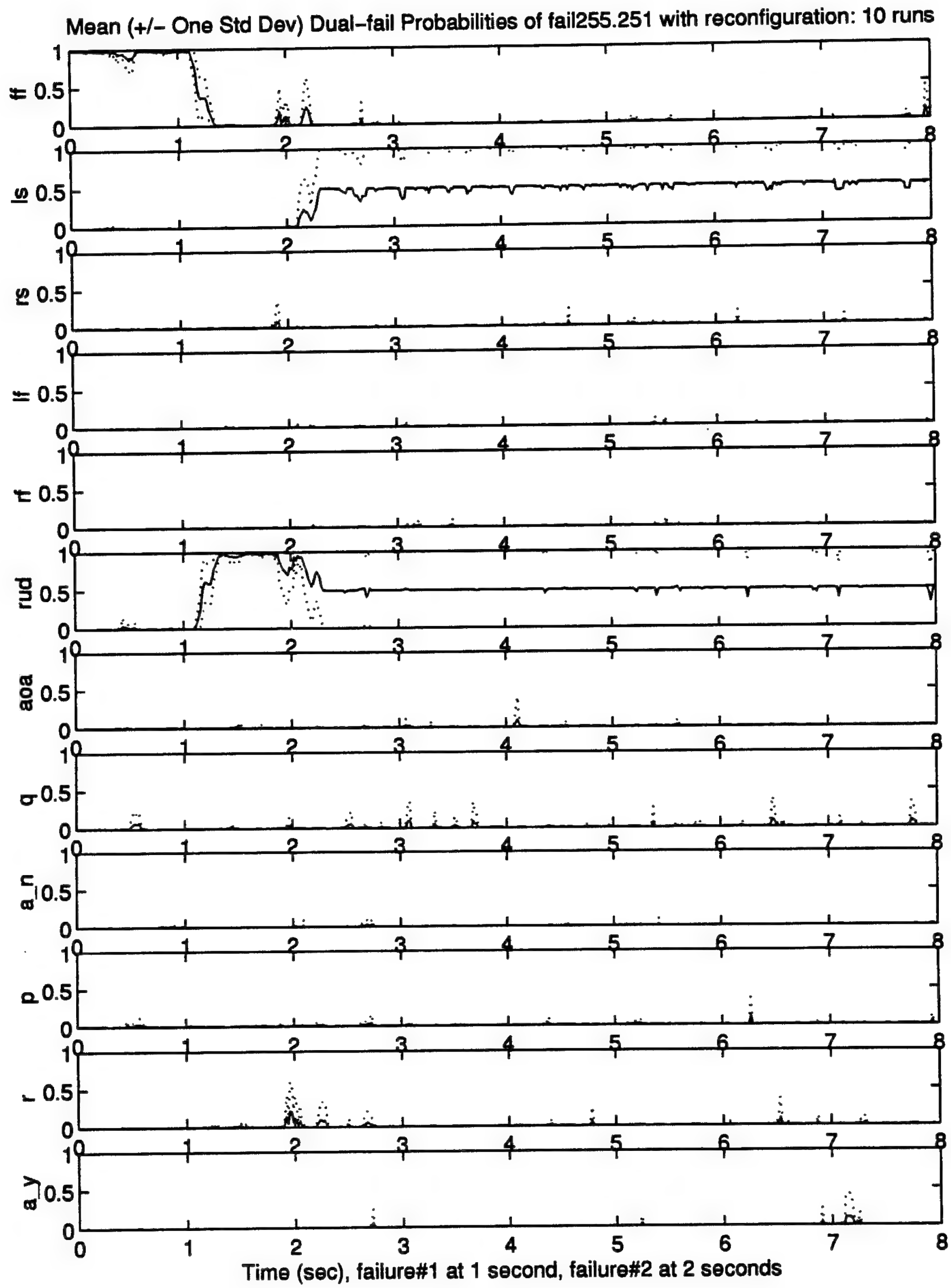

Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

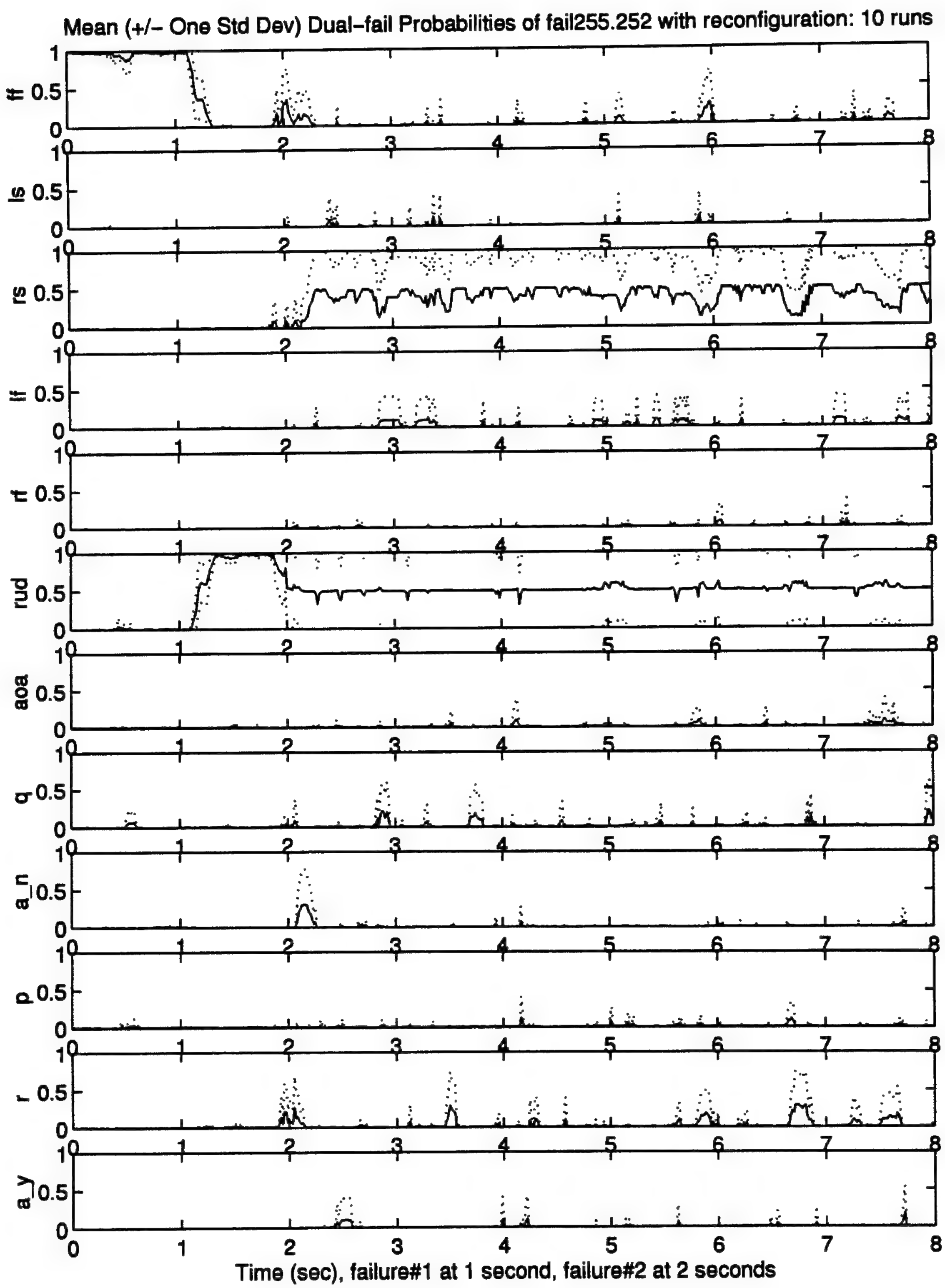


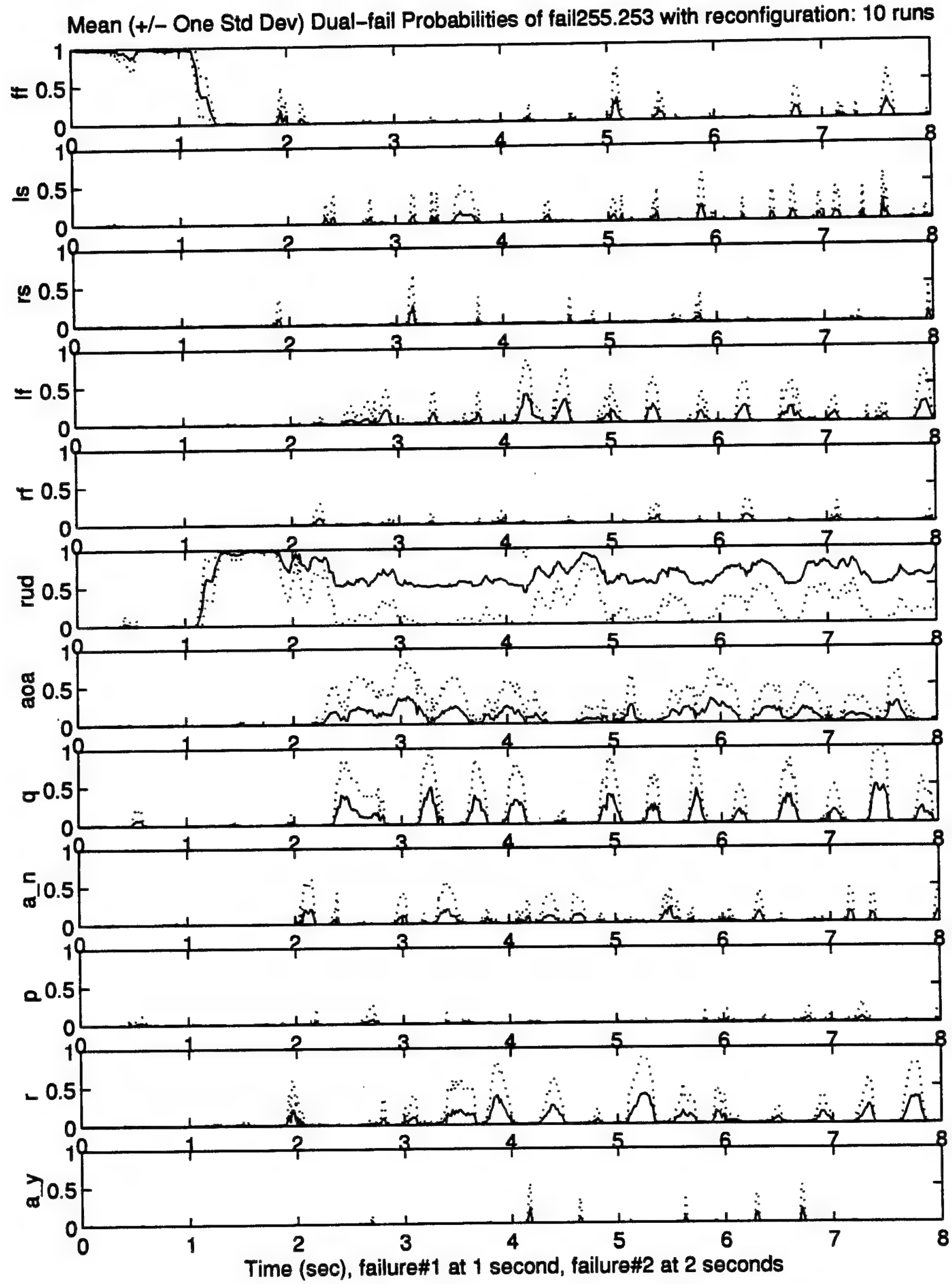
Mean (+/- One Std Dev) Dual-fail Probabilities of fail254.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



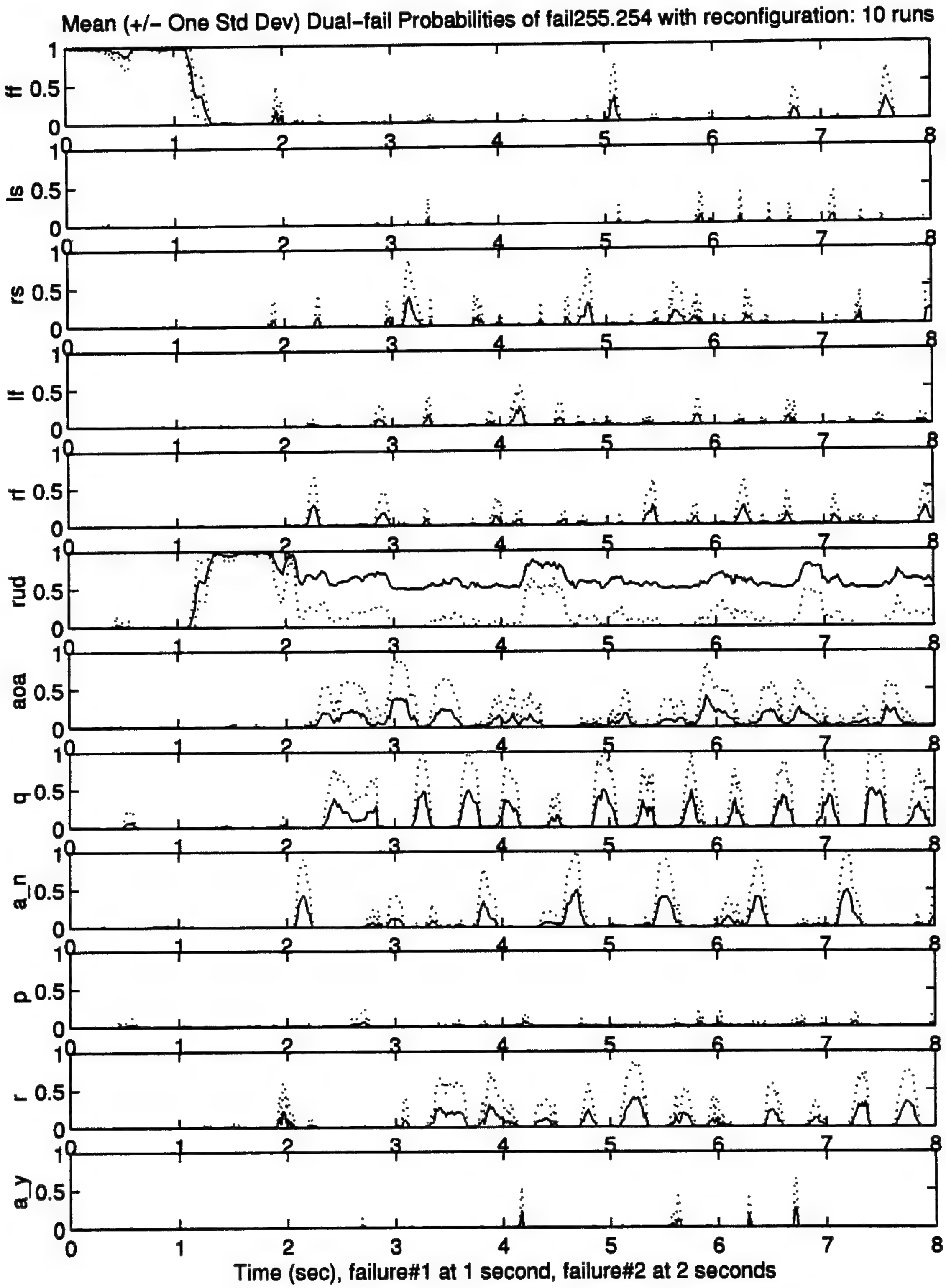
Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.250 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

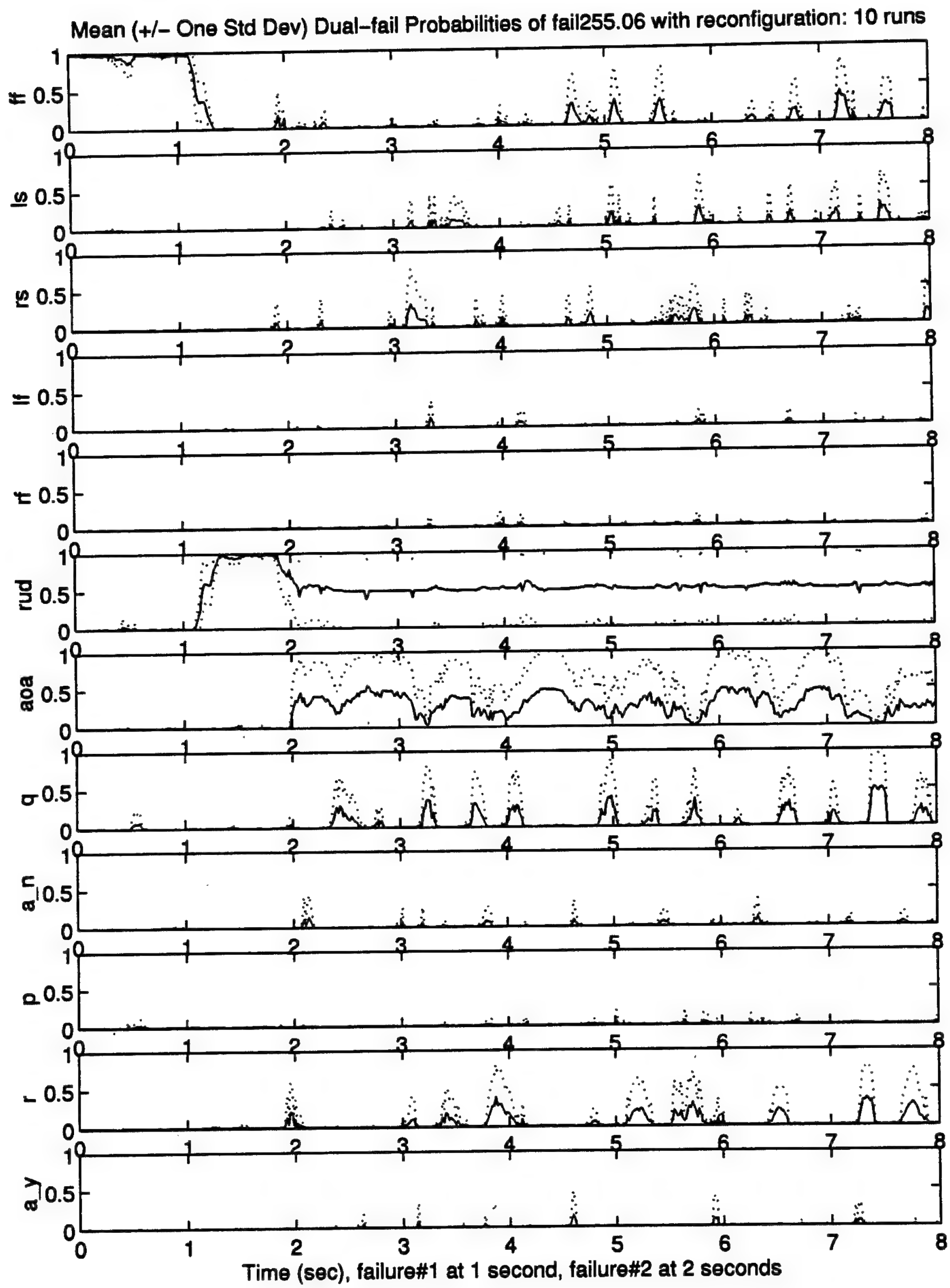

Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.251 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

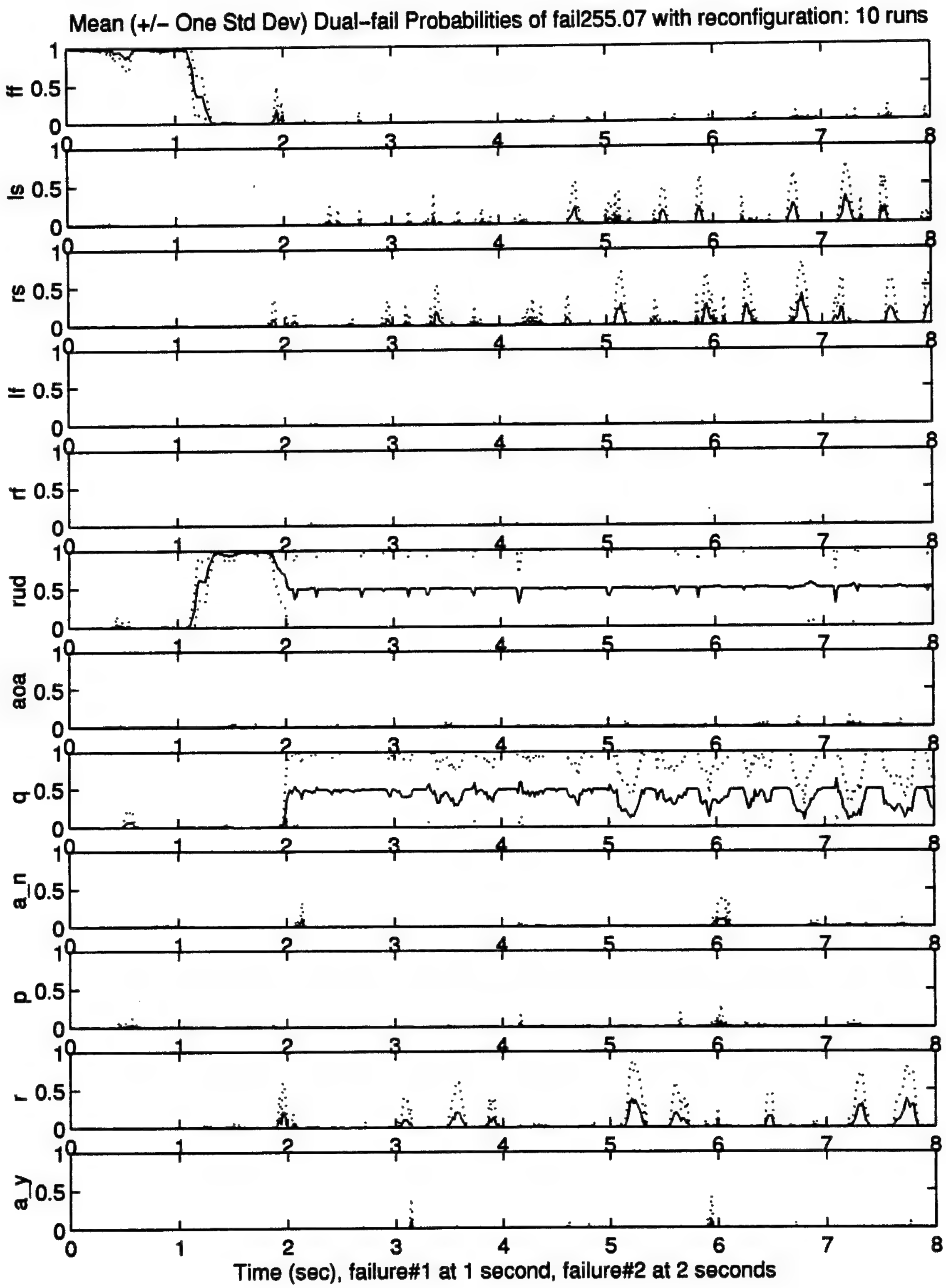

Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.252 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



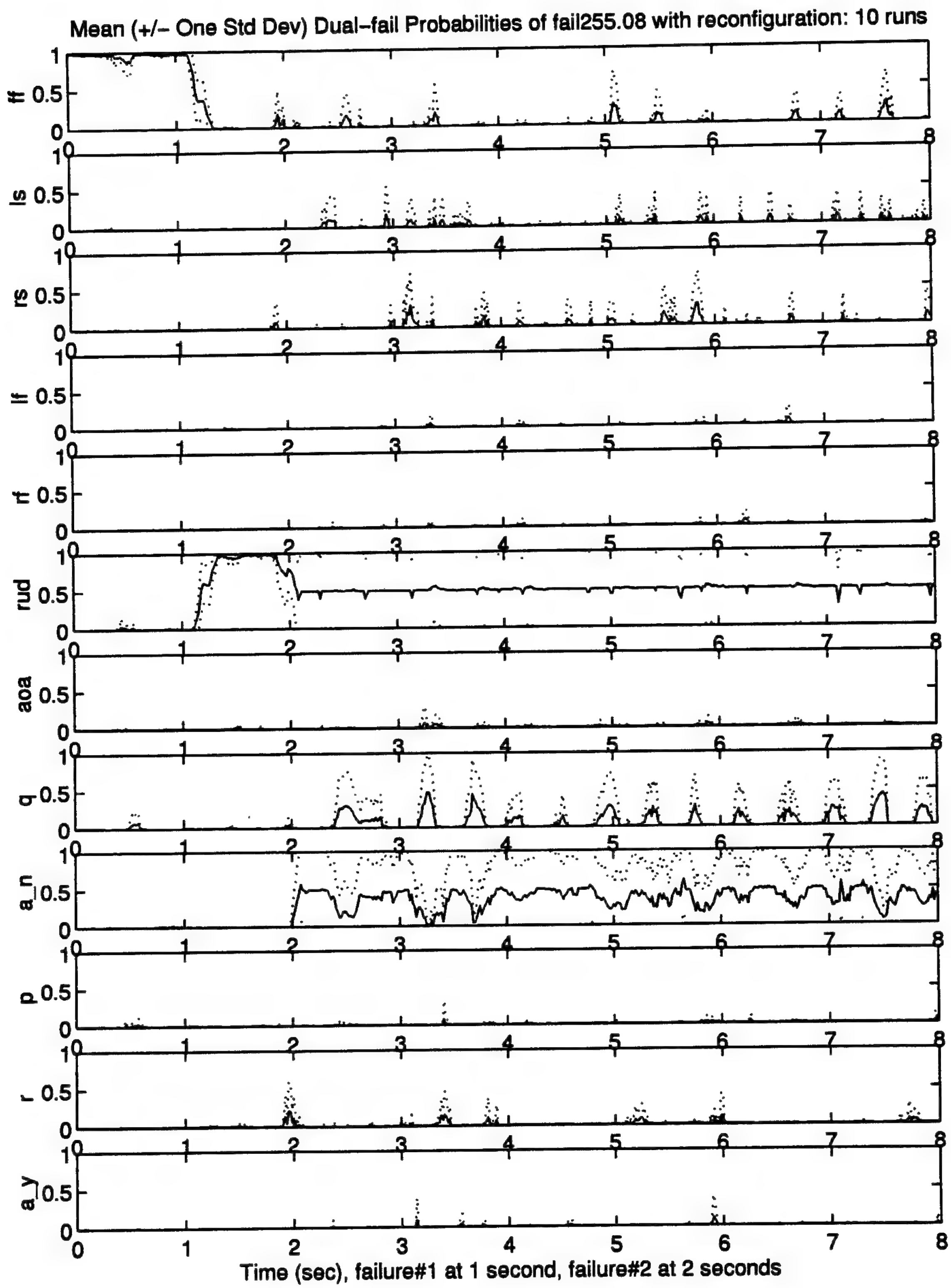
Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.253 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

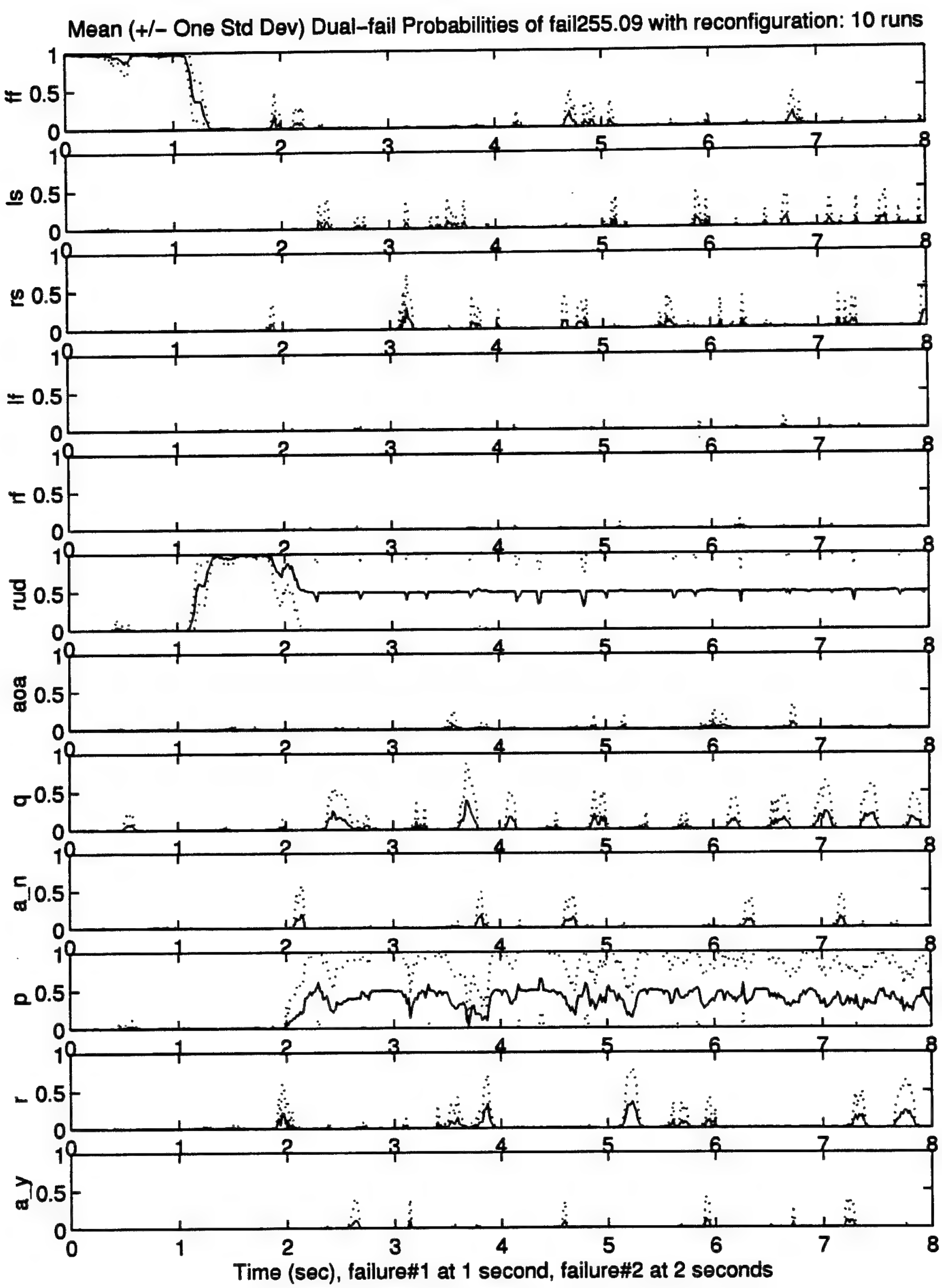

Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.254 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.06 with reconfiguration: 10 runs
lf
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

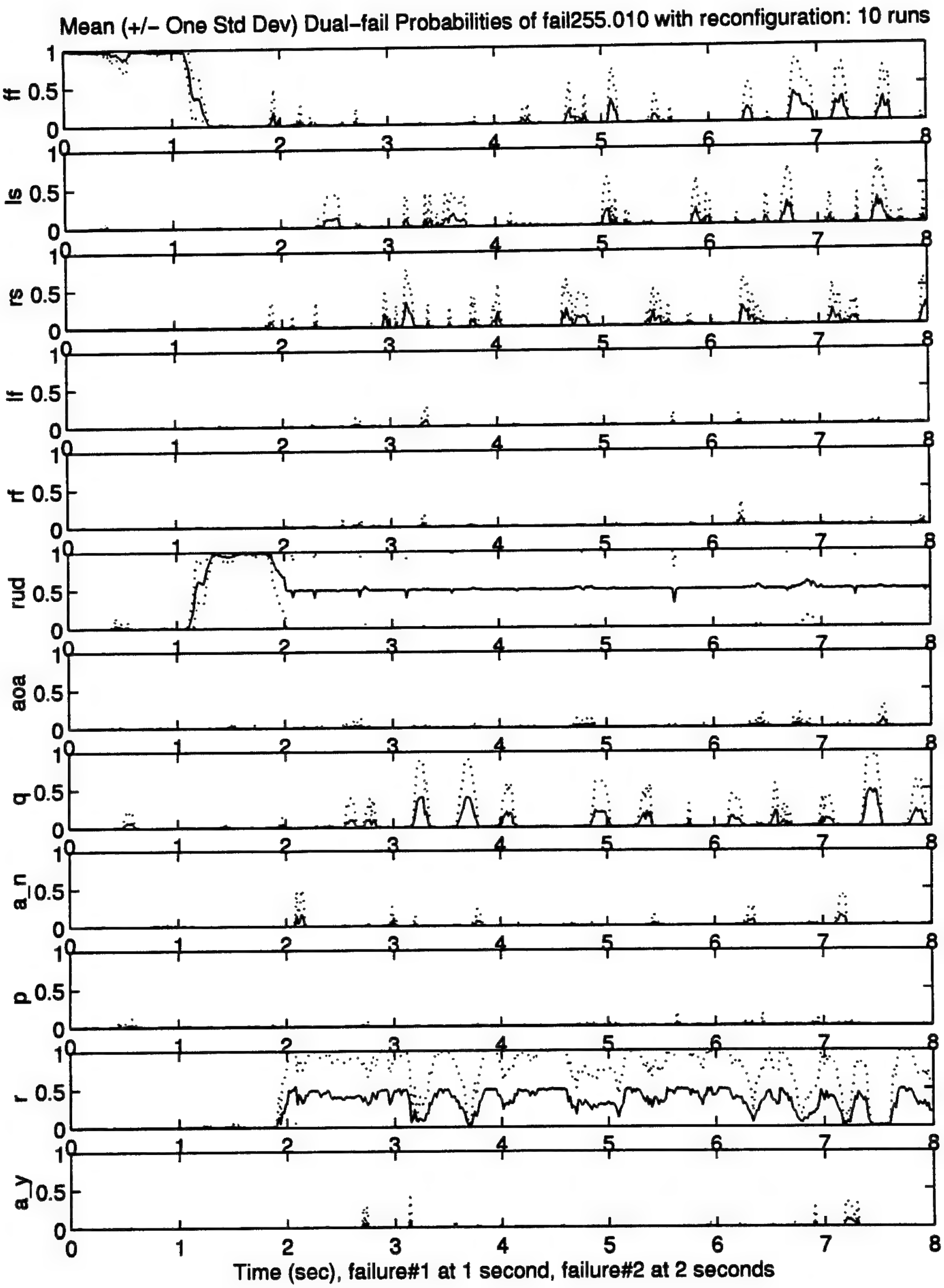


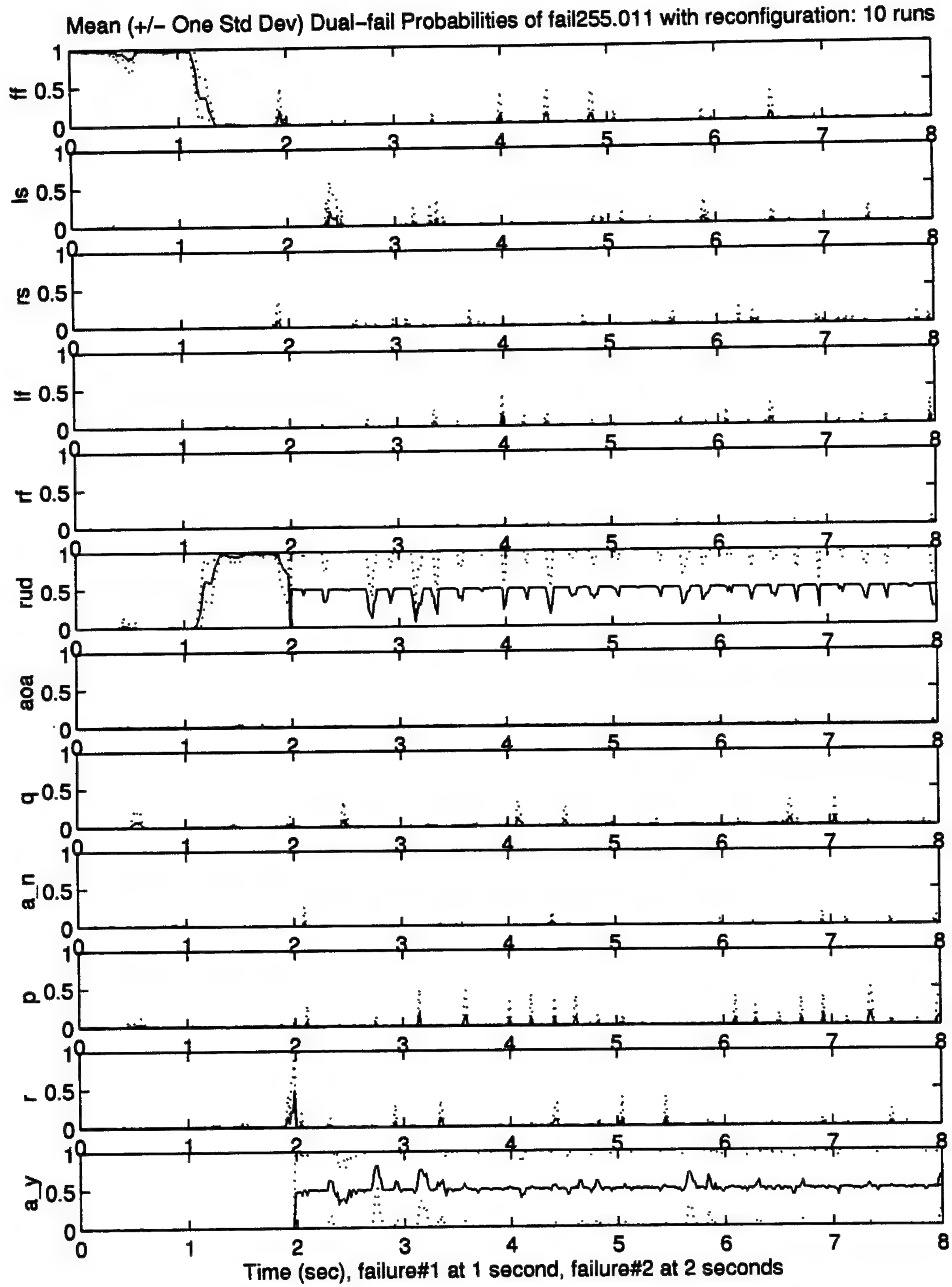
Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/− One Std Dev) Dual-fail Probabilities of fail255.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail255.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

Appendix D.3: Dual, 50% Actuator (ε =.5) and 50%-Actuator / Total -Sensor Impairments, Control Redistribution 'ON', Dither 'ON', No Maneuvers

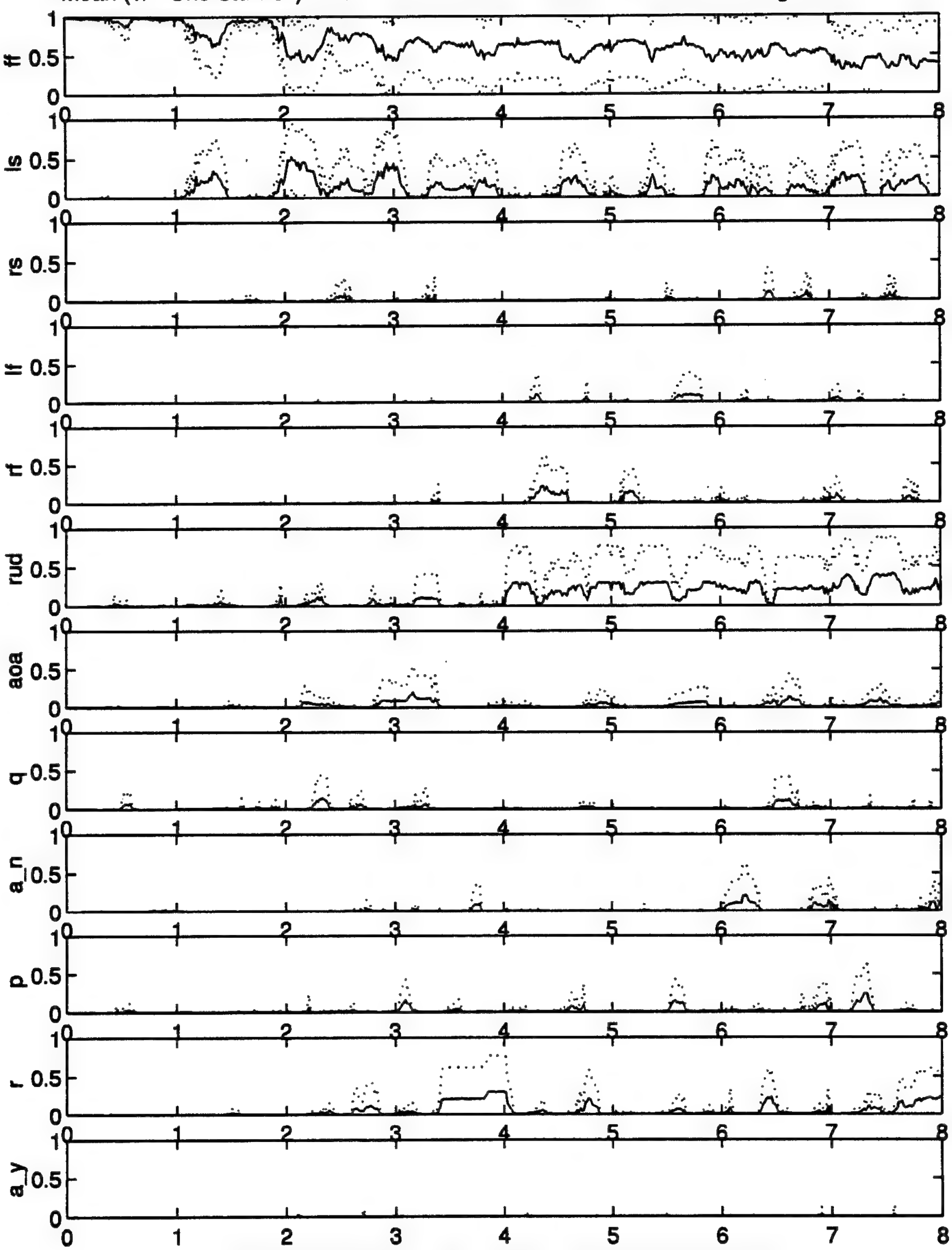
This appendix contains the individual probability plots for "50% actuator / 50% actuator" and "50% actuator / total sensor" dual impairment scenarios, *with* Control Reconfiguration (Redistribution) and with control dithering (Section 4.13.3). The first impairment is inserted at 1 second, followed by the second impairment at 2 seconds, and in all cases, there is no aircraft maneuvering. Table D.3 on the following page lists the impairment cases, by case number, which are to be found in this appendix. The leftmost column of Table D.3 represents the first impairment occurring at 1 second, while the top row represents the second impairment occurring at 2 seconds. The table entries list the failure codes found in the plot titles for the failure case represented by the table row and column. **Bold** entries correspond to cases of no second impairment. As an example, the entry for a 50% left stabilator (LS) impairment at 1 second, followed by a 50% right flaperon (RF) impairment at 2 seconds is found in entry '(LS, RF)' in the table, and the corresponding failure case is 'fail501.504'. The convention was to use effectiveness, ε, in naming the plots, and hence 'fail<u>50</u>1.<u>50</u>4' corresponds to 50% actuator *effectiveness*, or a 50% actuator impairment. The probability plot will contain this code ('fail501.504') in the plot title. In fact, for this specific case, the plot title is: "Mean (+ / - One Std Dev) Dual-fail Probabilities of fail501.504 with reconfiguration: 10 runs". The reader is reminded that, after the switch to the Level '1' filter bank, the meanings of the probability traces in the plots (except for the fully functional trace, which retains the same meaning) change to that of the first impairment *plus* the second impairment.

Second Impairment

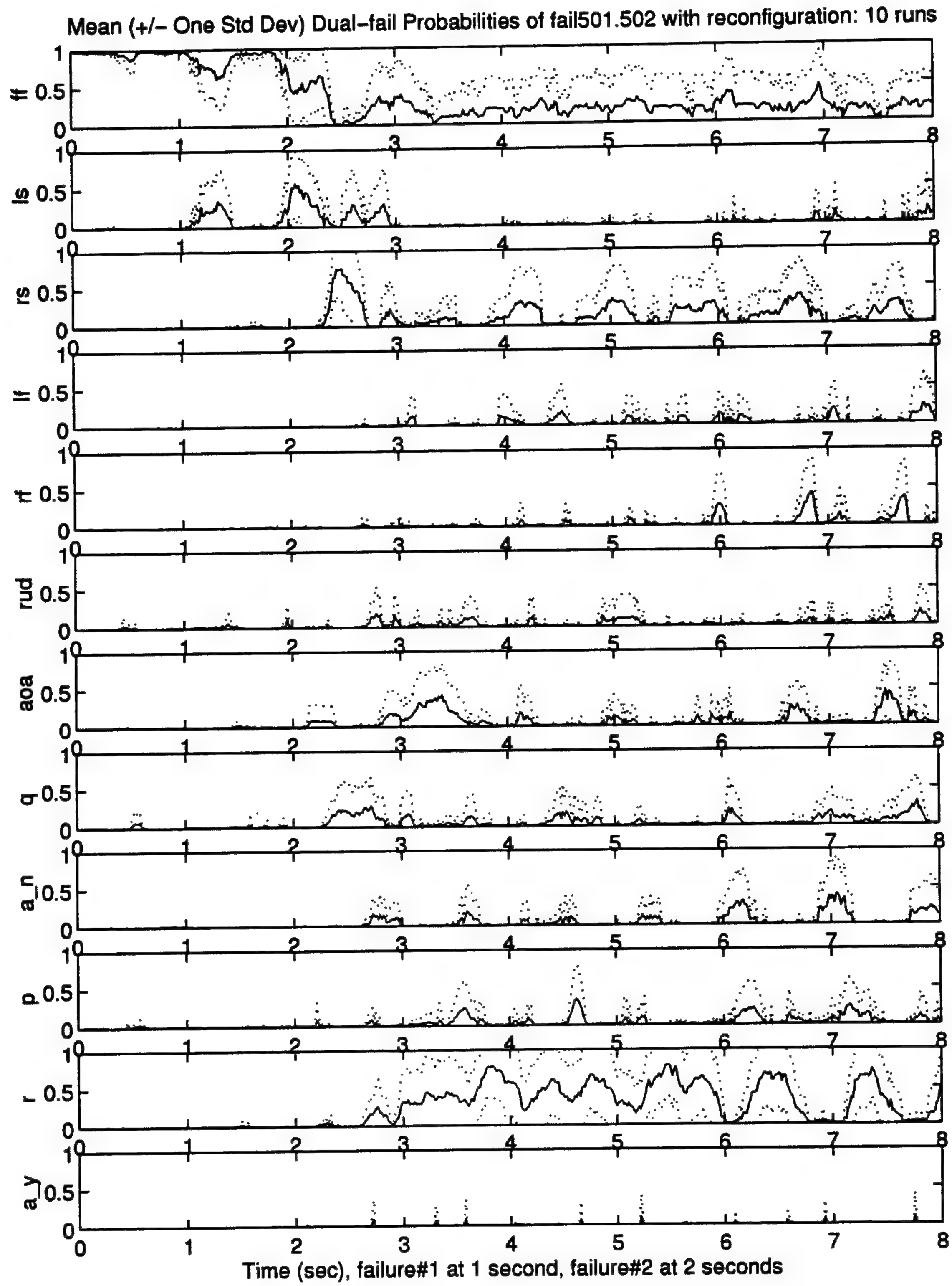
	LS (50%)	RS (50%)	LF (50%)	RF (50%)	RUD (50%)	AOA (100%)	Q (100%)	A_n (100%)	P (100%)	R (100%)	A_y (100%)
LS (50%)	**fail501.500**	fail501.502	fail501.503	fail501.504	fail501.505	fail501.06	fail501.07	fail501.08	fail501.09	fail501.010	fail501.011
RS (50%)	fail502.501	**fail502.500**	fail502.503	fail502.504	fail502.505	fail502.06	fail502.07	fail502.08	fail502.09	fail502.010	fail502.011
LF (50%)	fail503.501	fail503.502	**fail503.500**	fail503.504	fail503.505	fail503.06	fail503.07	fail503.08	fail503.09	fail503.010	fail503.011
RF (50%)	fail504.501	fai504.502	fail504.503	**fail504.500**	fail504.505	fail504.06	fail504.07	fail504.08	fail504.09	fail504.010	fail504.011
RUD (50%)	fail505.501	fail505.502	fail505.503	fail505.504	**fail505.500**	fail505.06	fail505.07	fail505.08	fail505.09	fail505.010	fail505.011

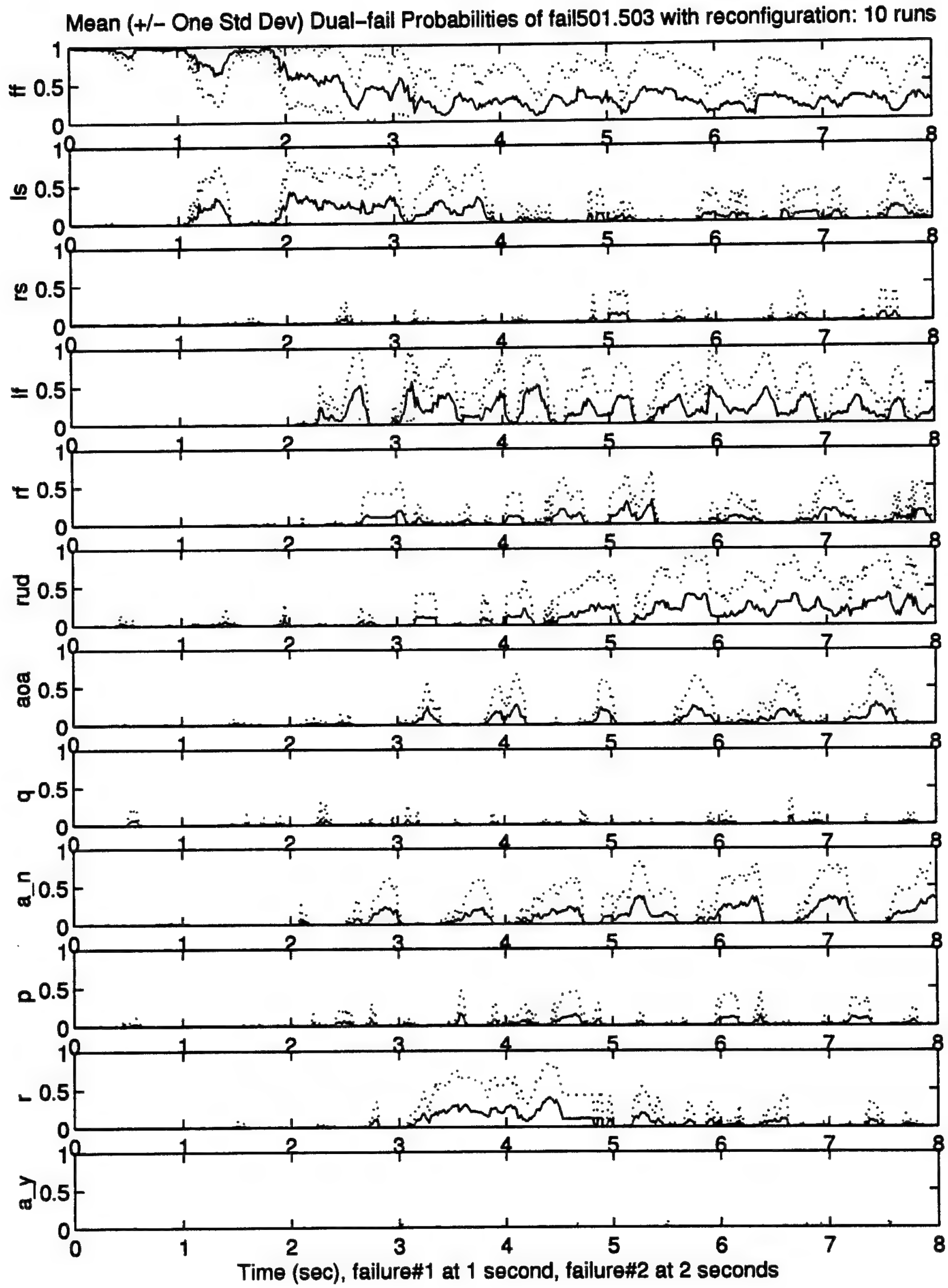
Table D.3 A Listing of All Probability Plots Found in Appendix D.3 by Failure Case

Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.500 with reconfiguration: 10 runs

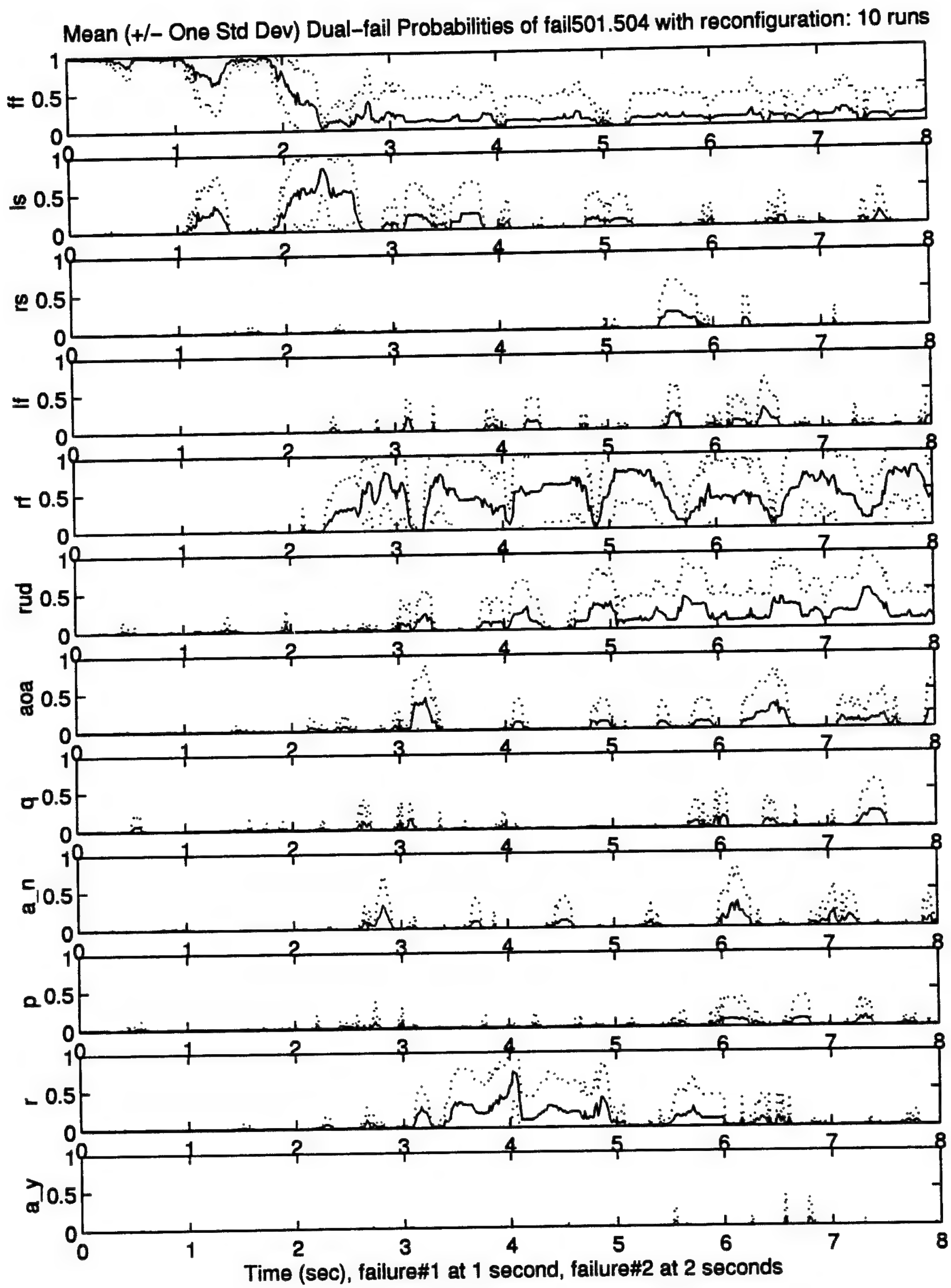


Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

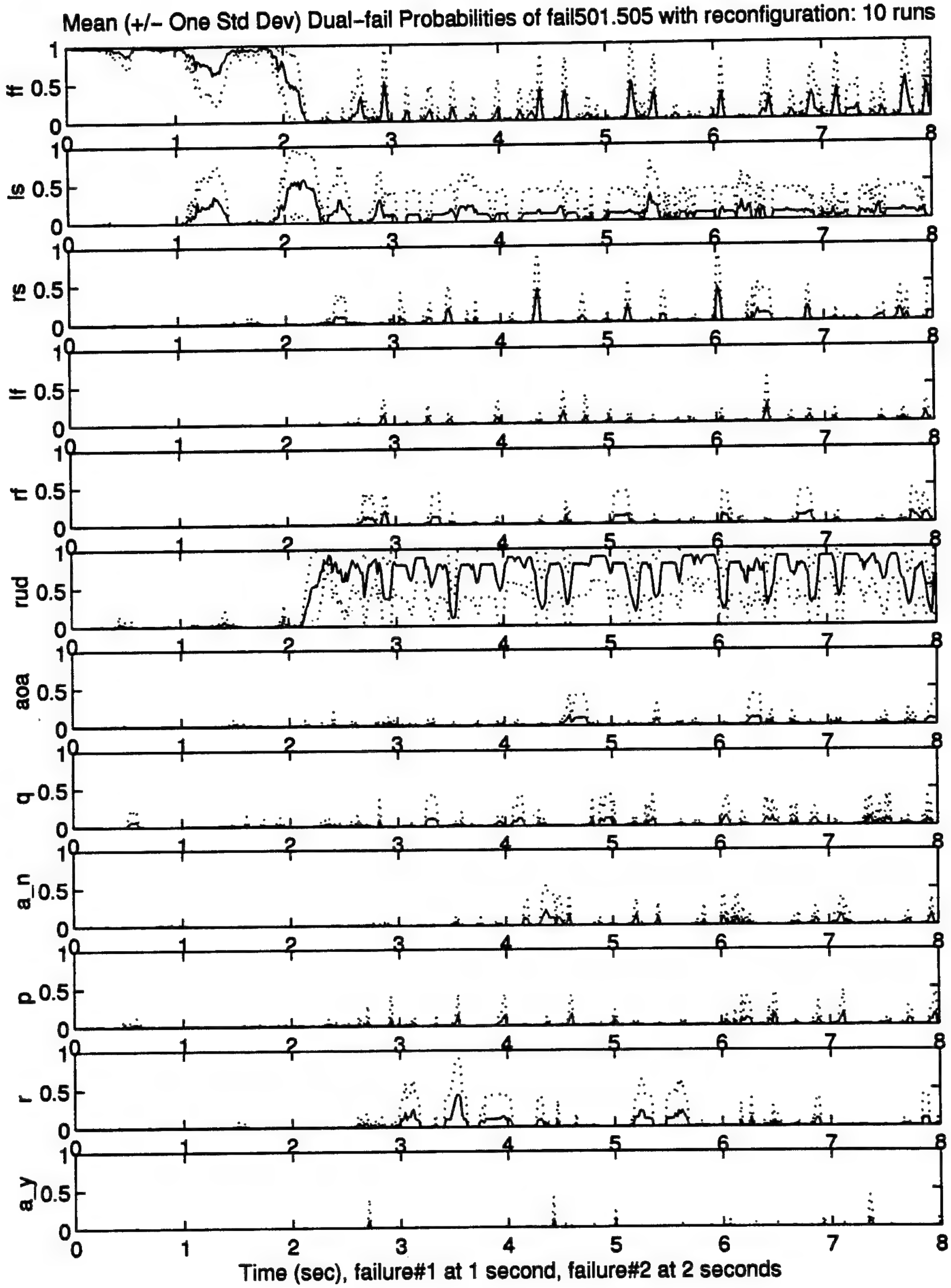

Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.502 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



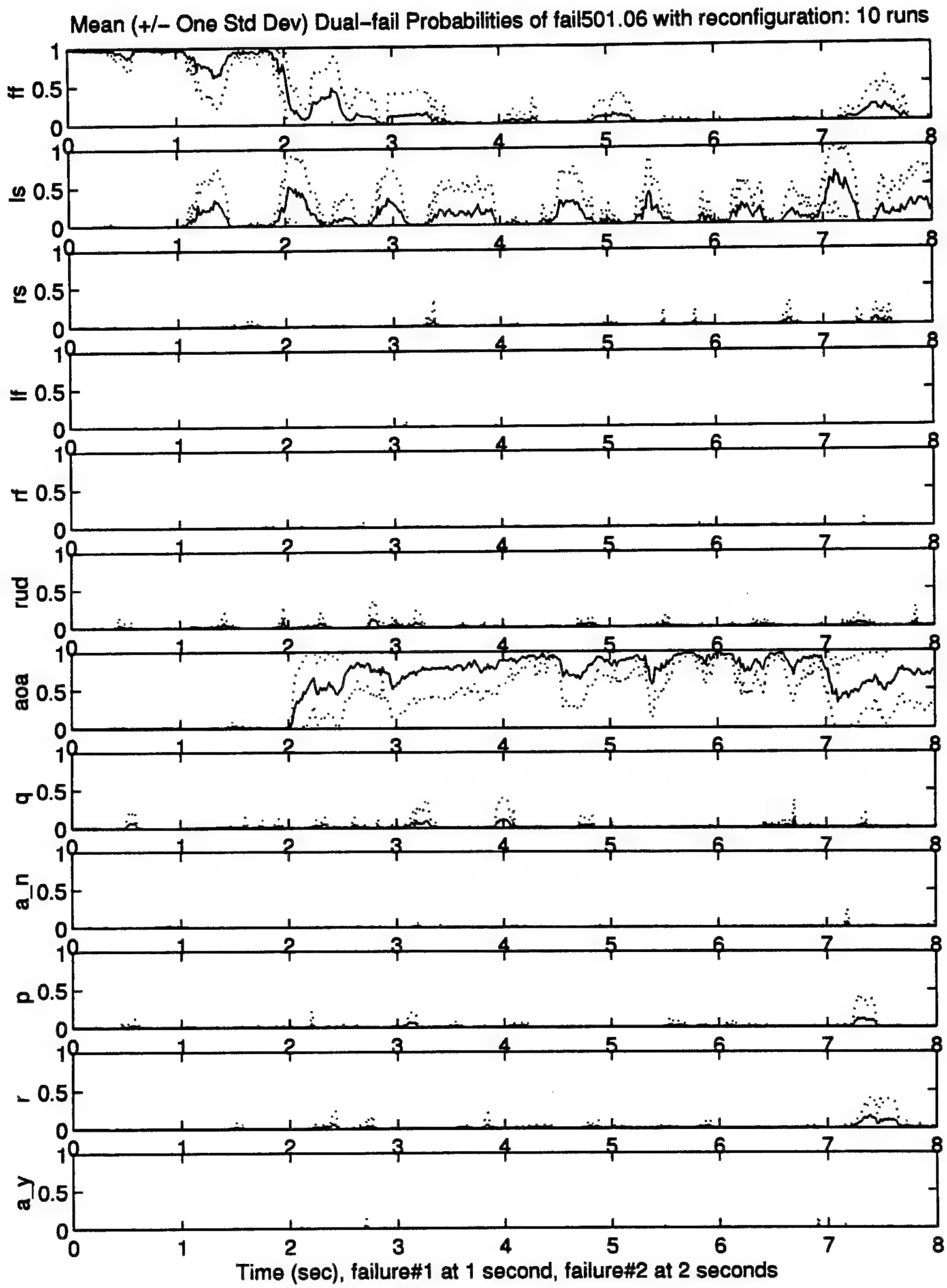
Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.503 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

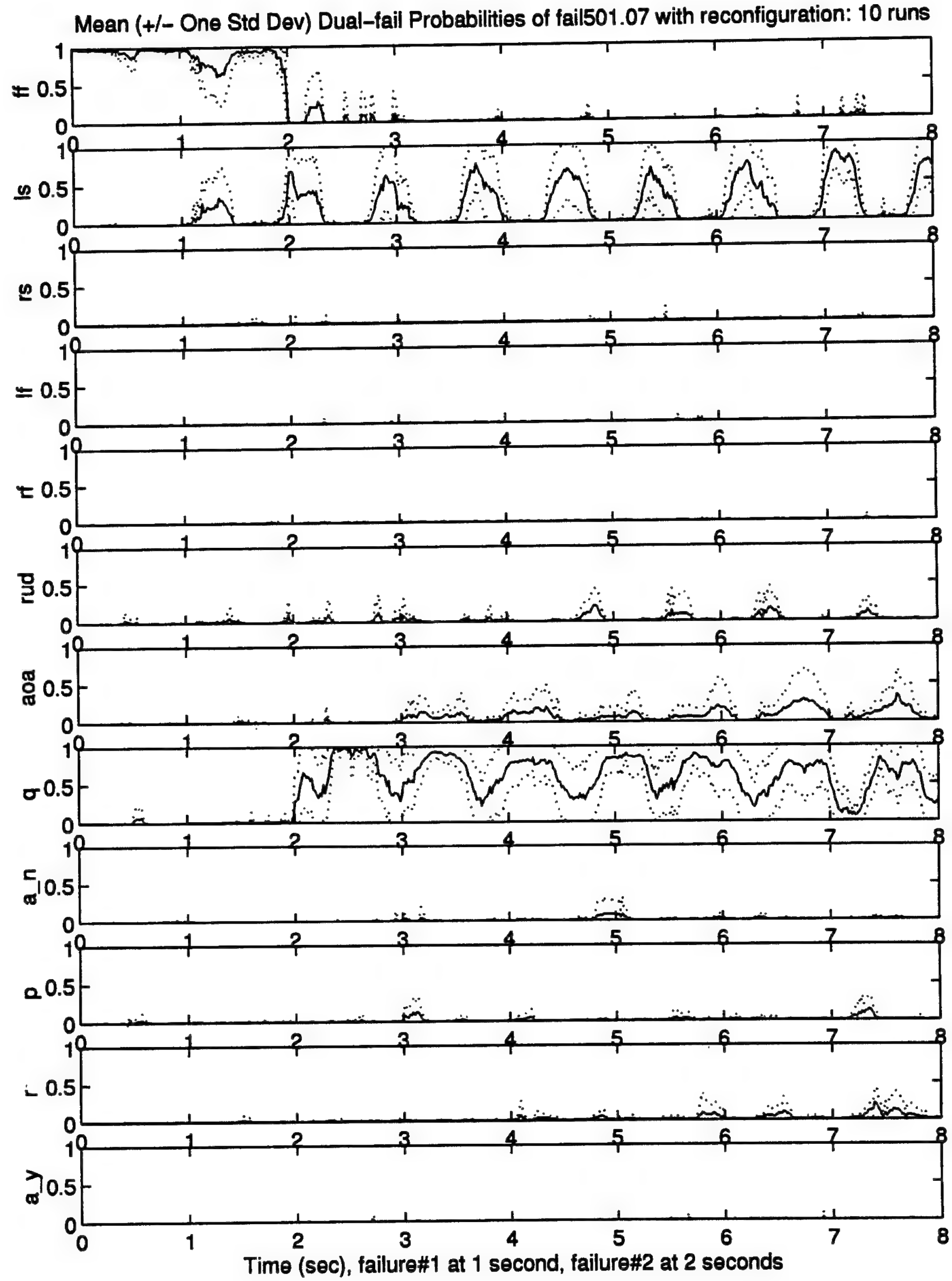


Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.504 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

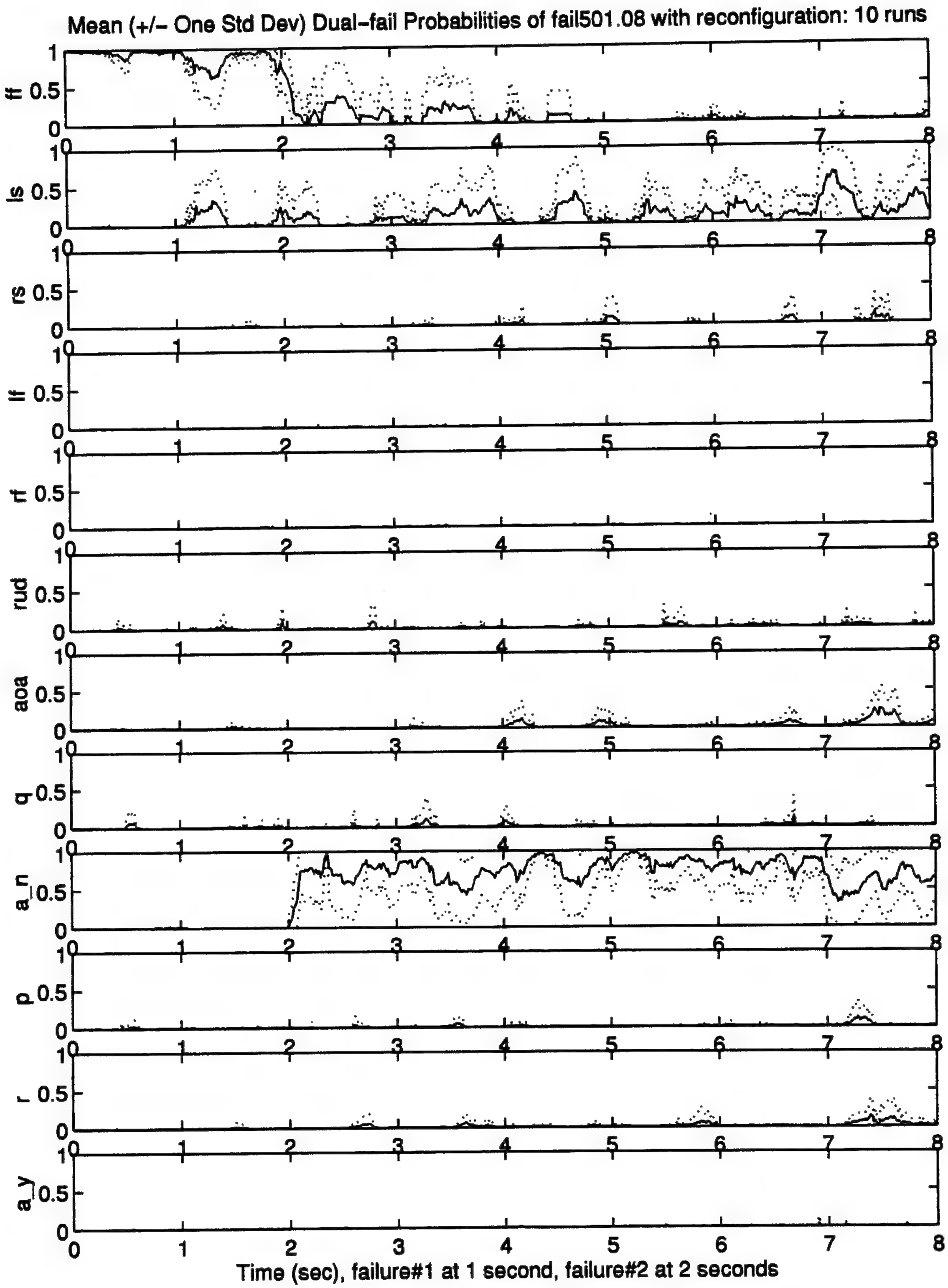


Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.505 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

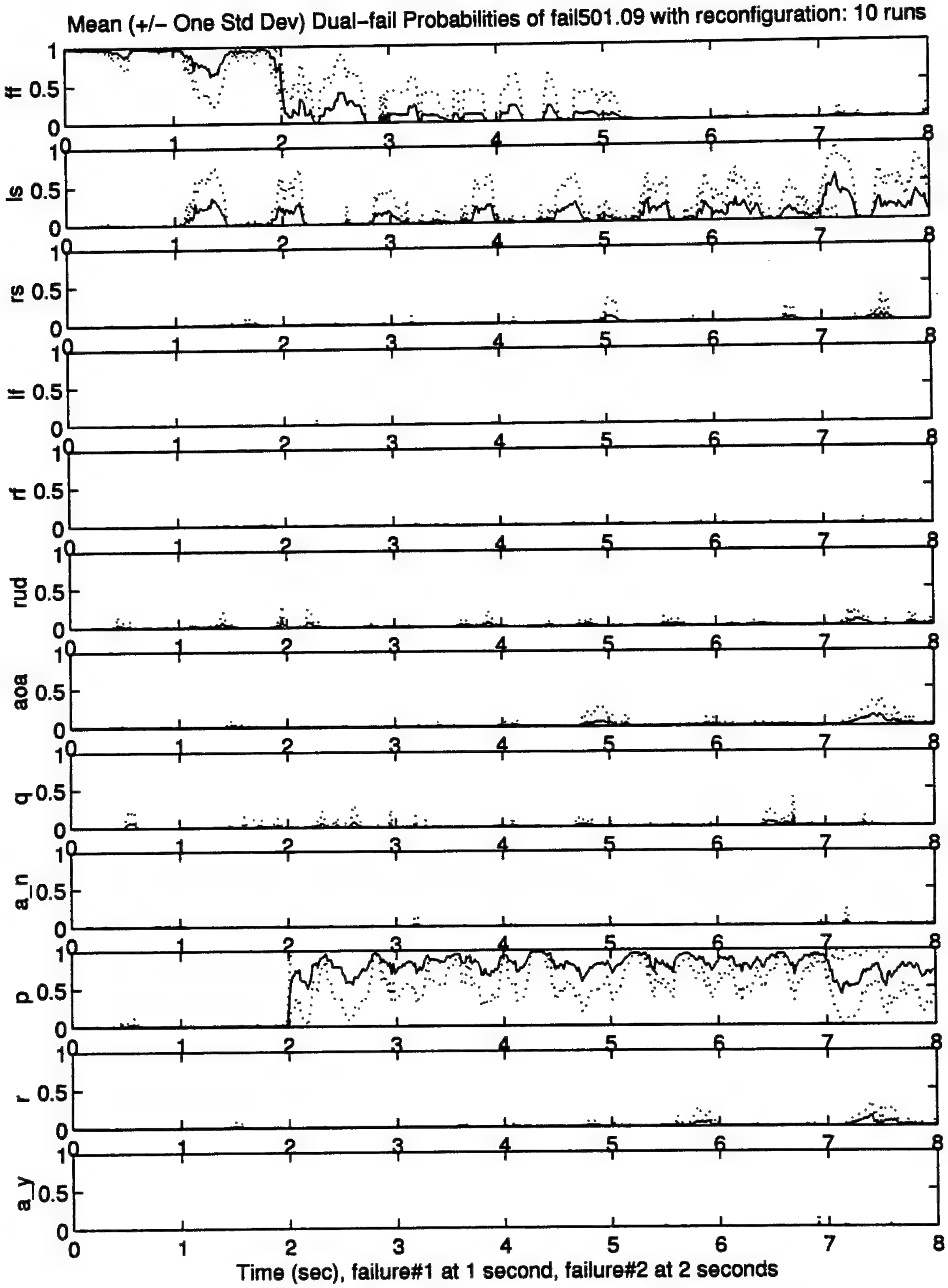

Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.06 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

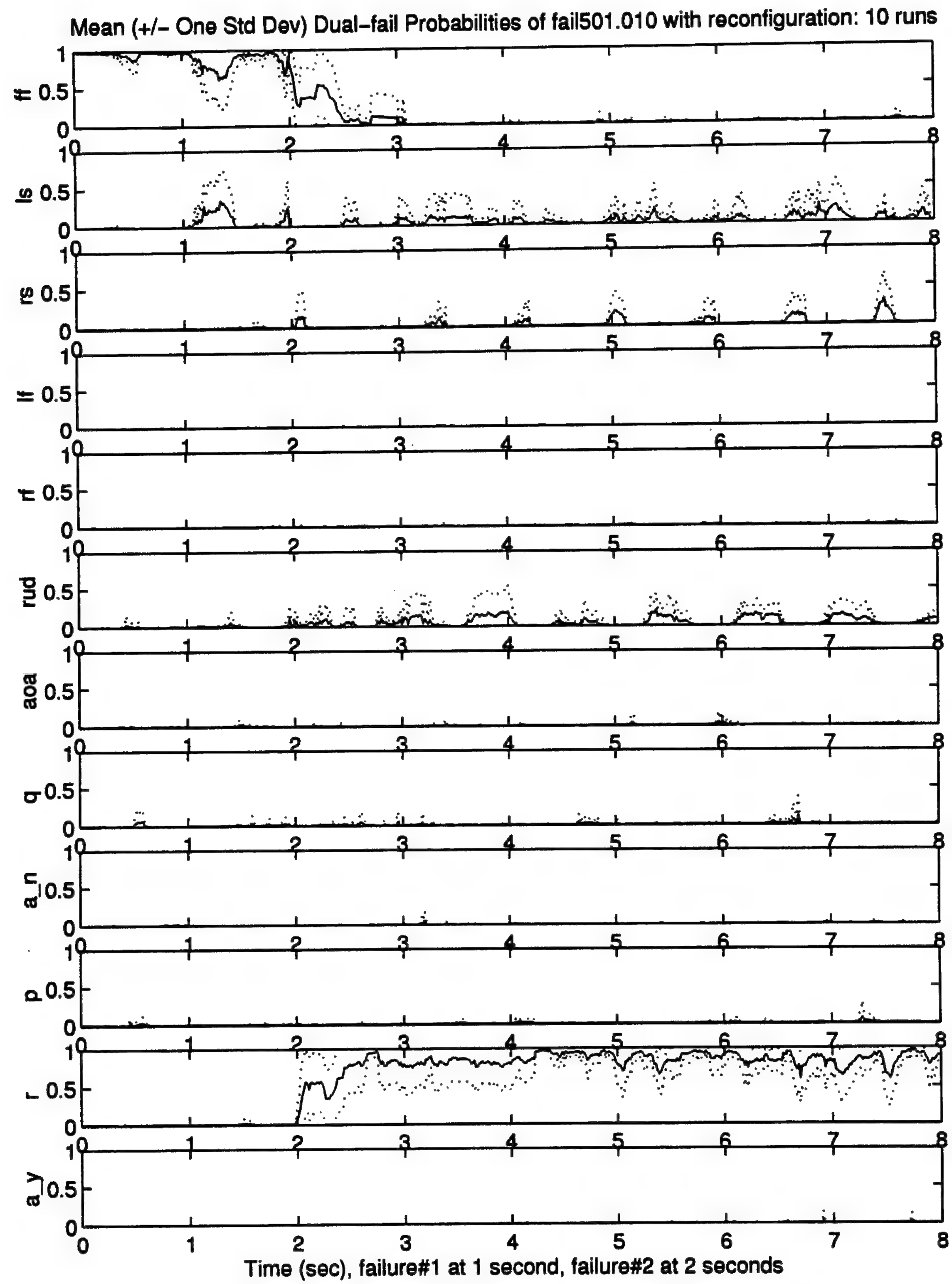


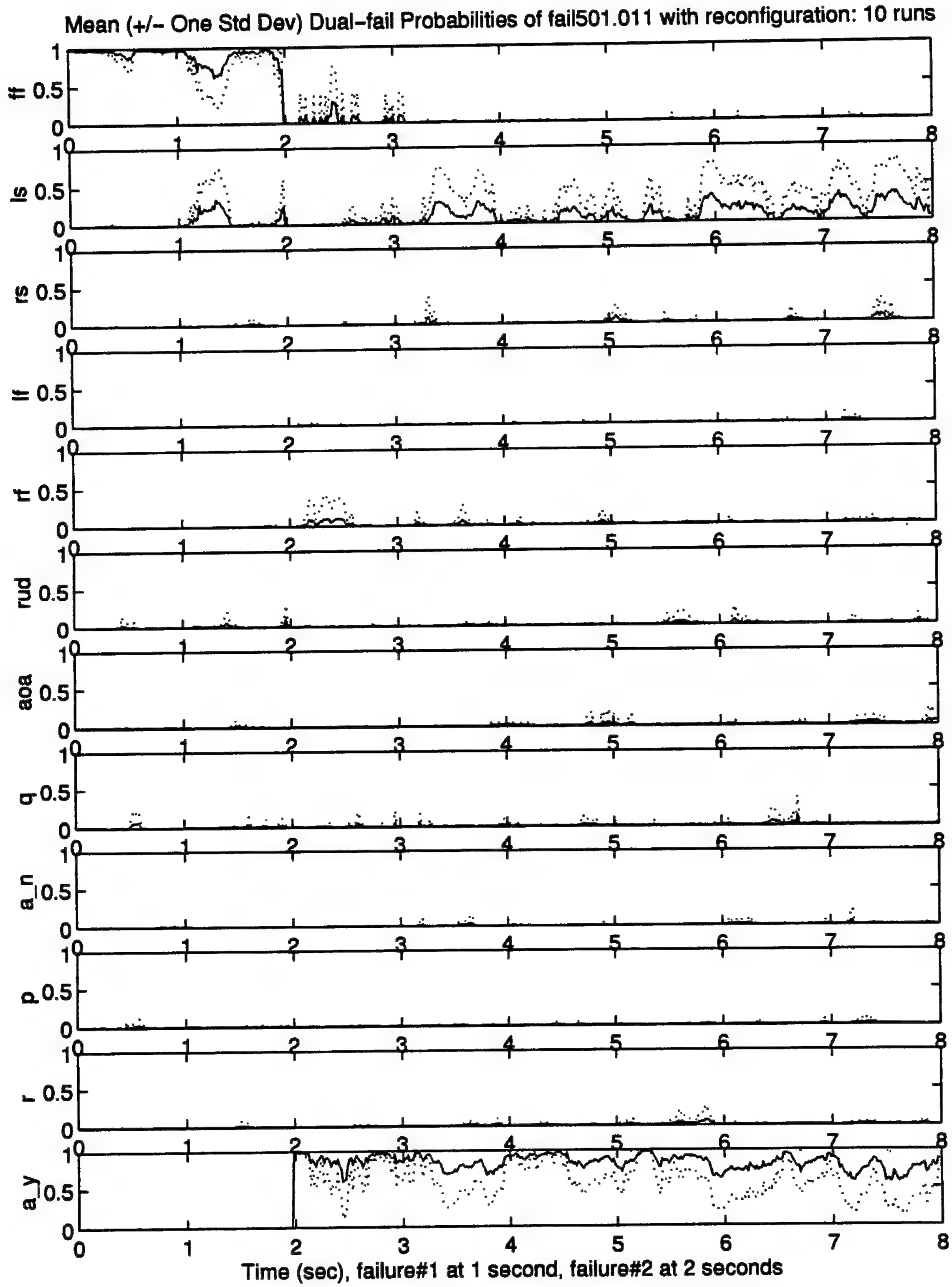
Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



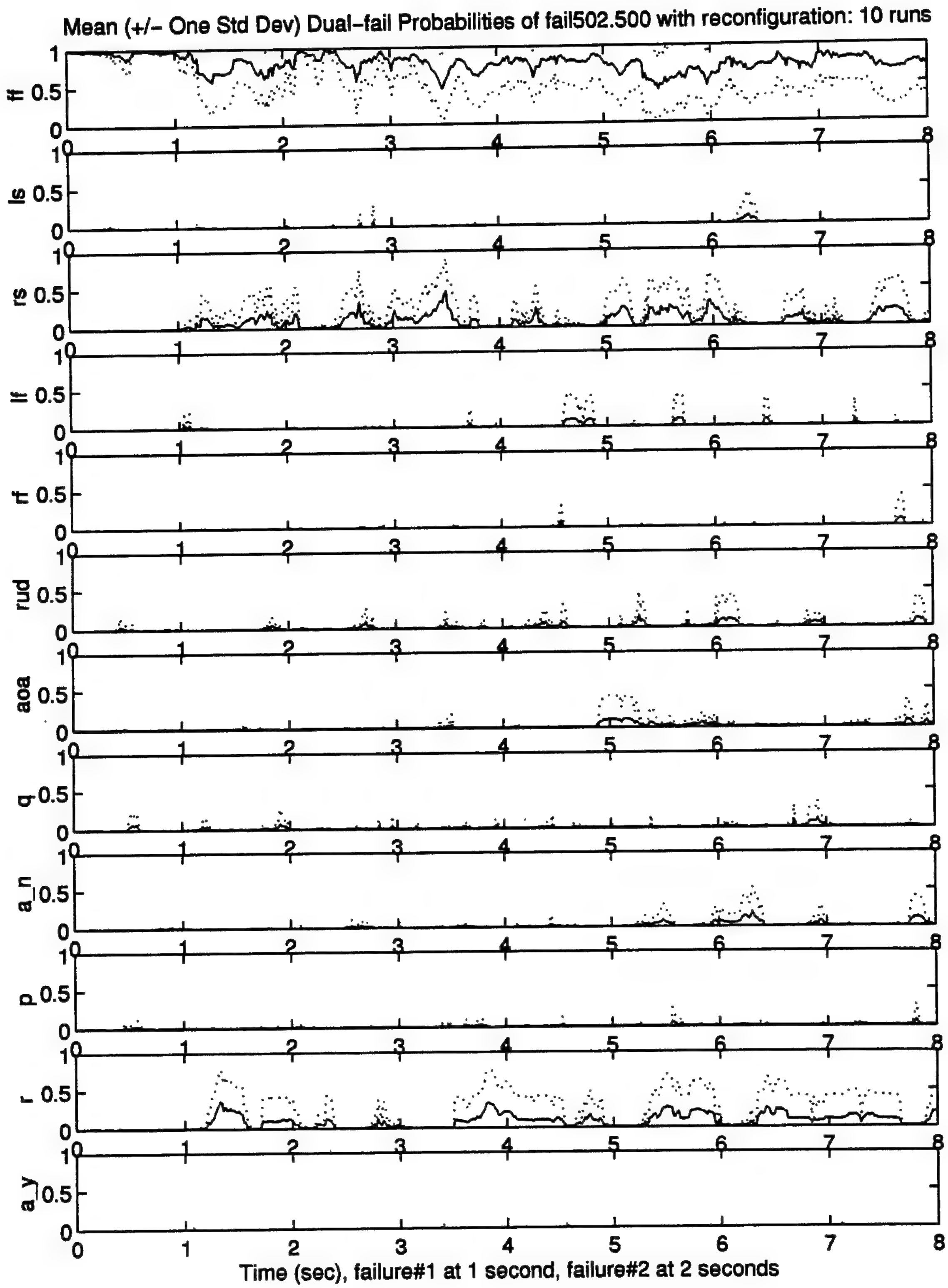
Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

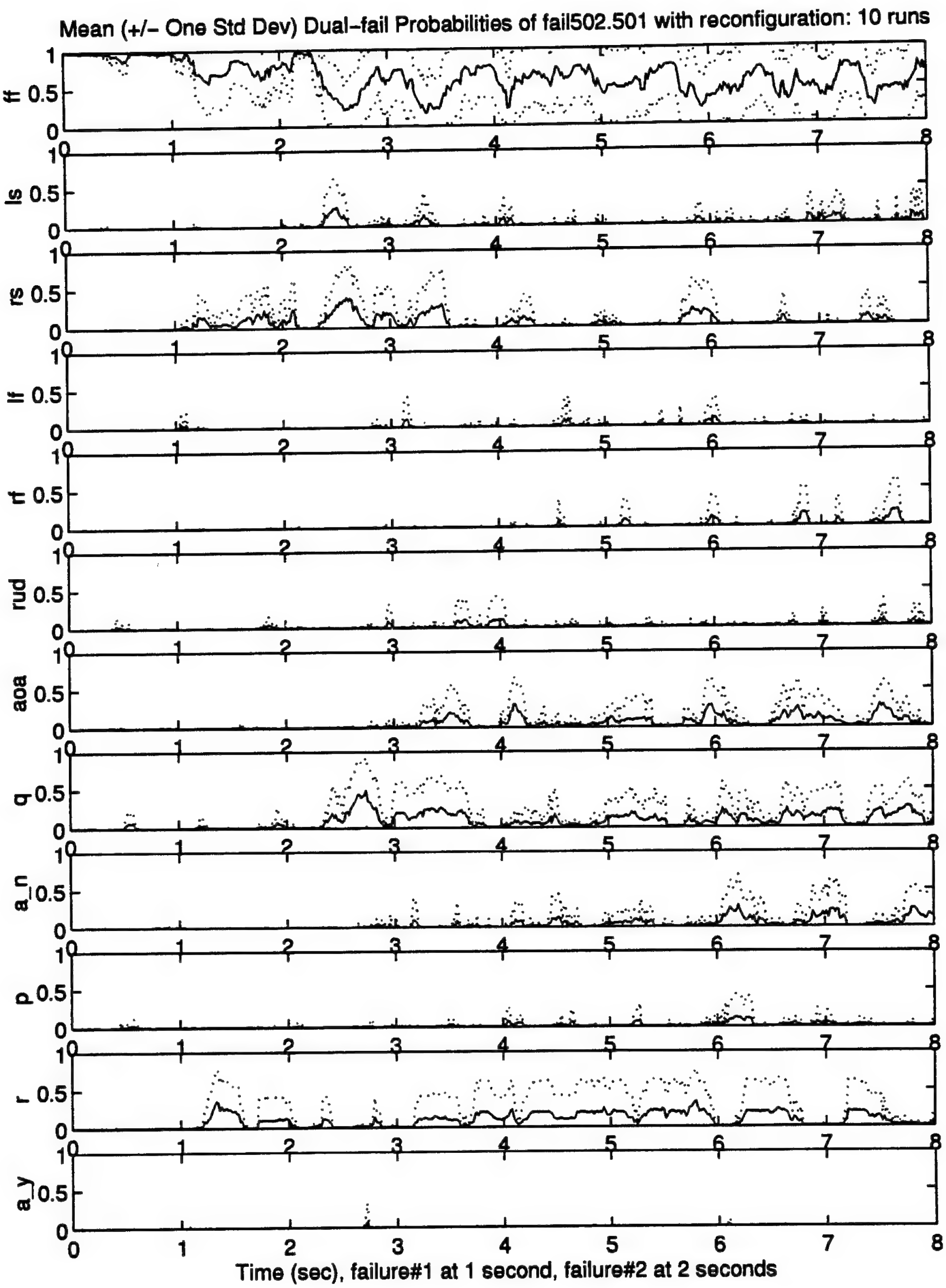

Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

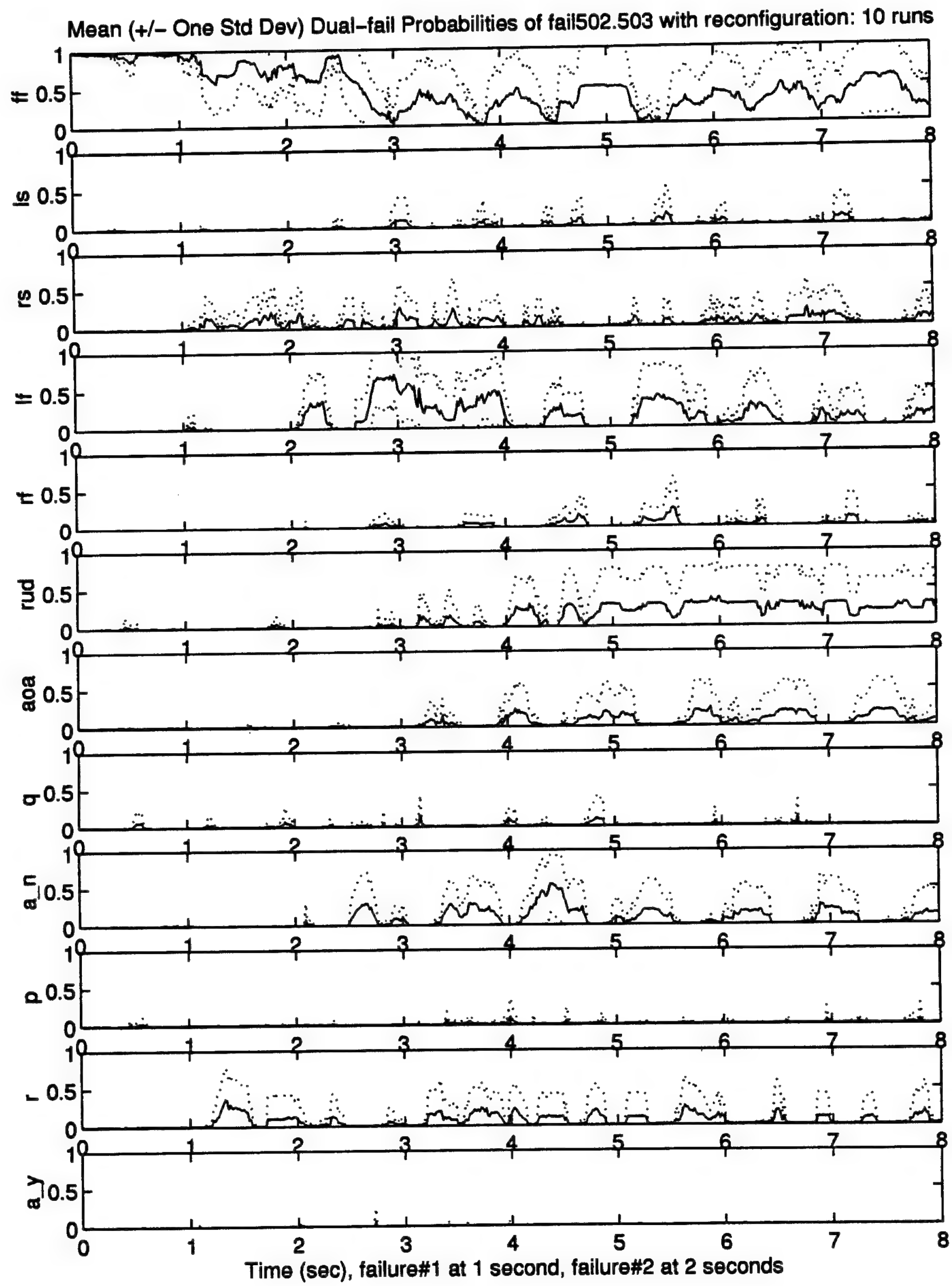


Mean (+/- One Std Dev) Dual-fail Probabilities of fail501.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

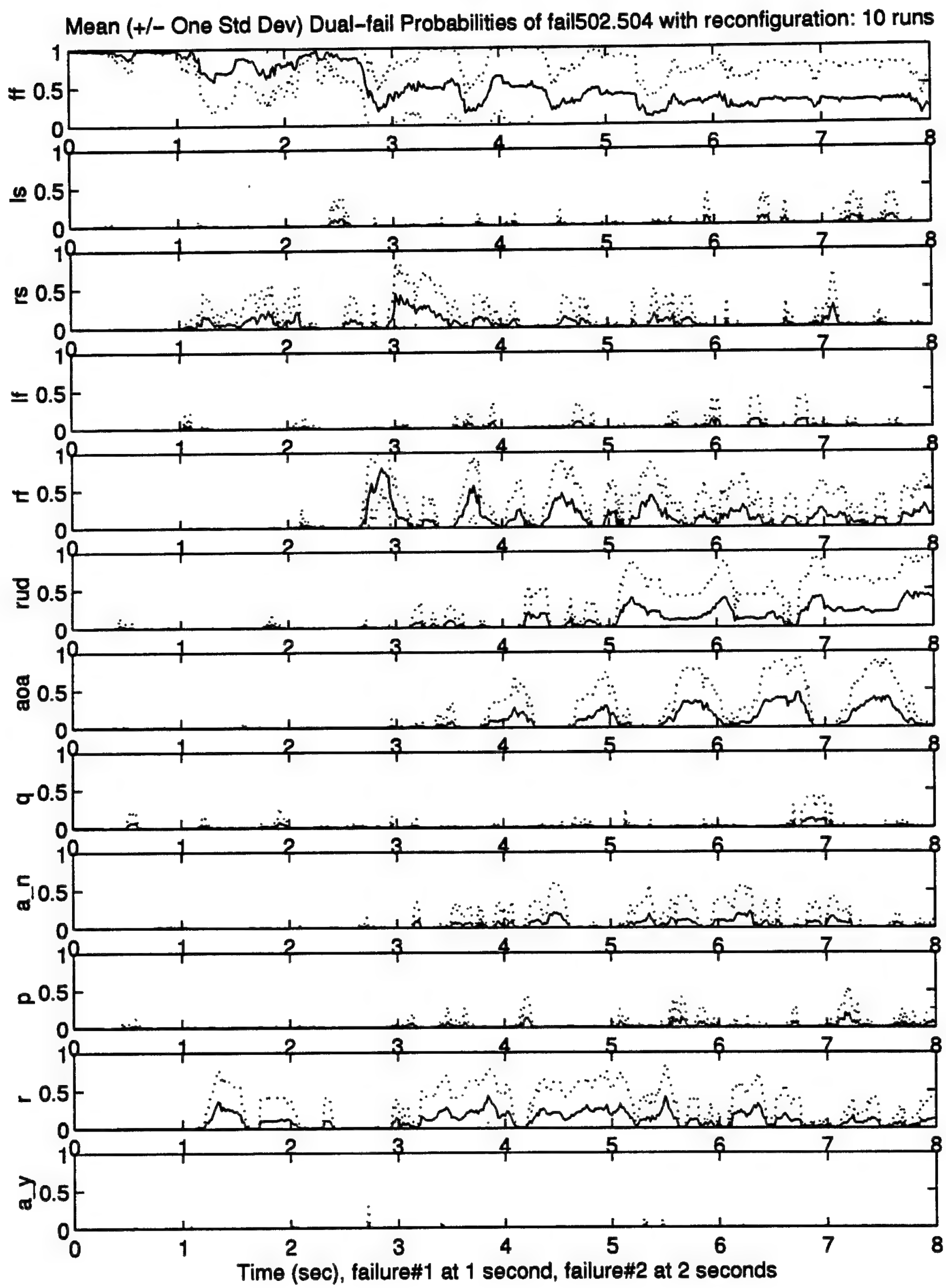


Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.500 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

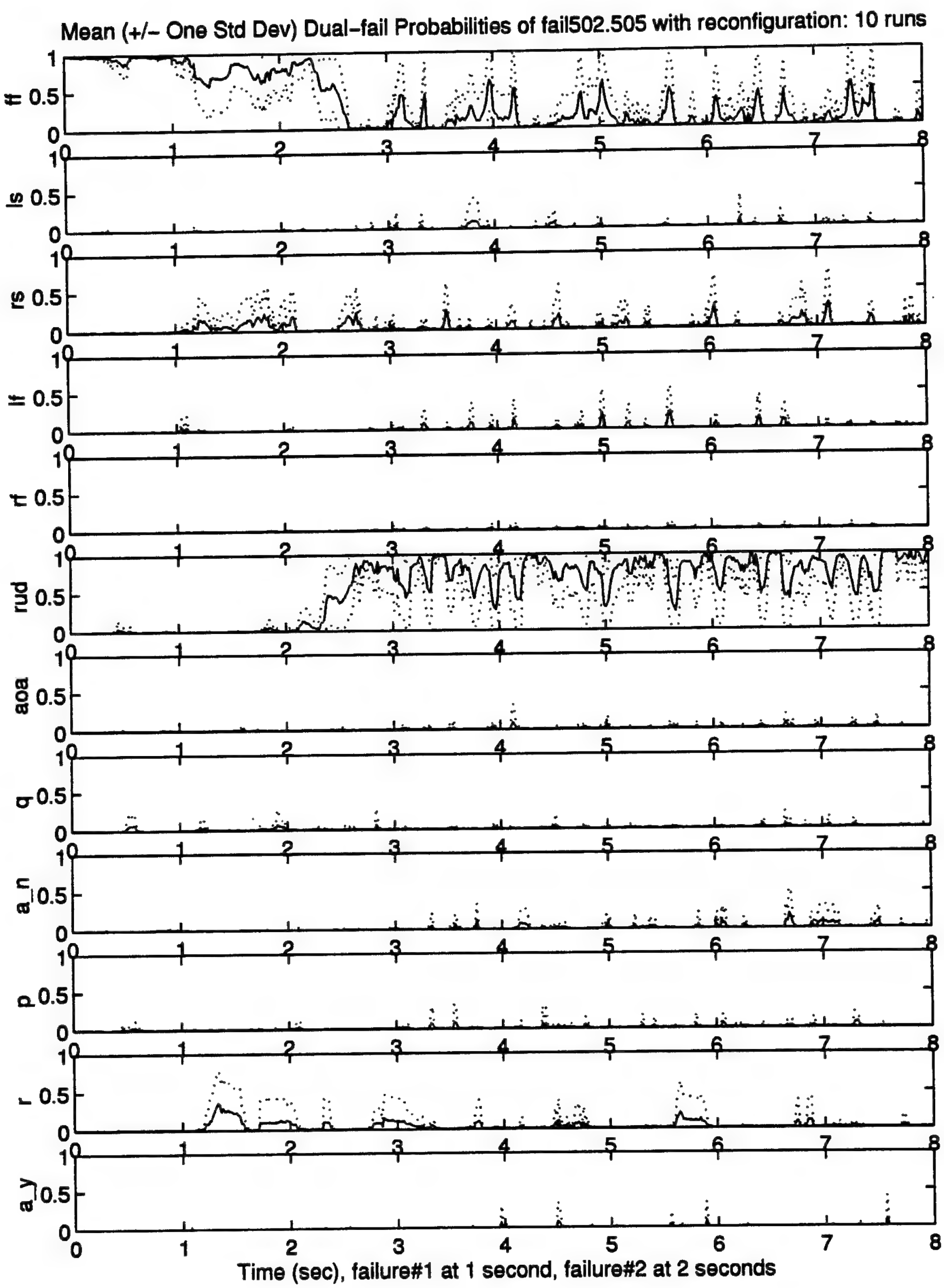

Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.501 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



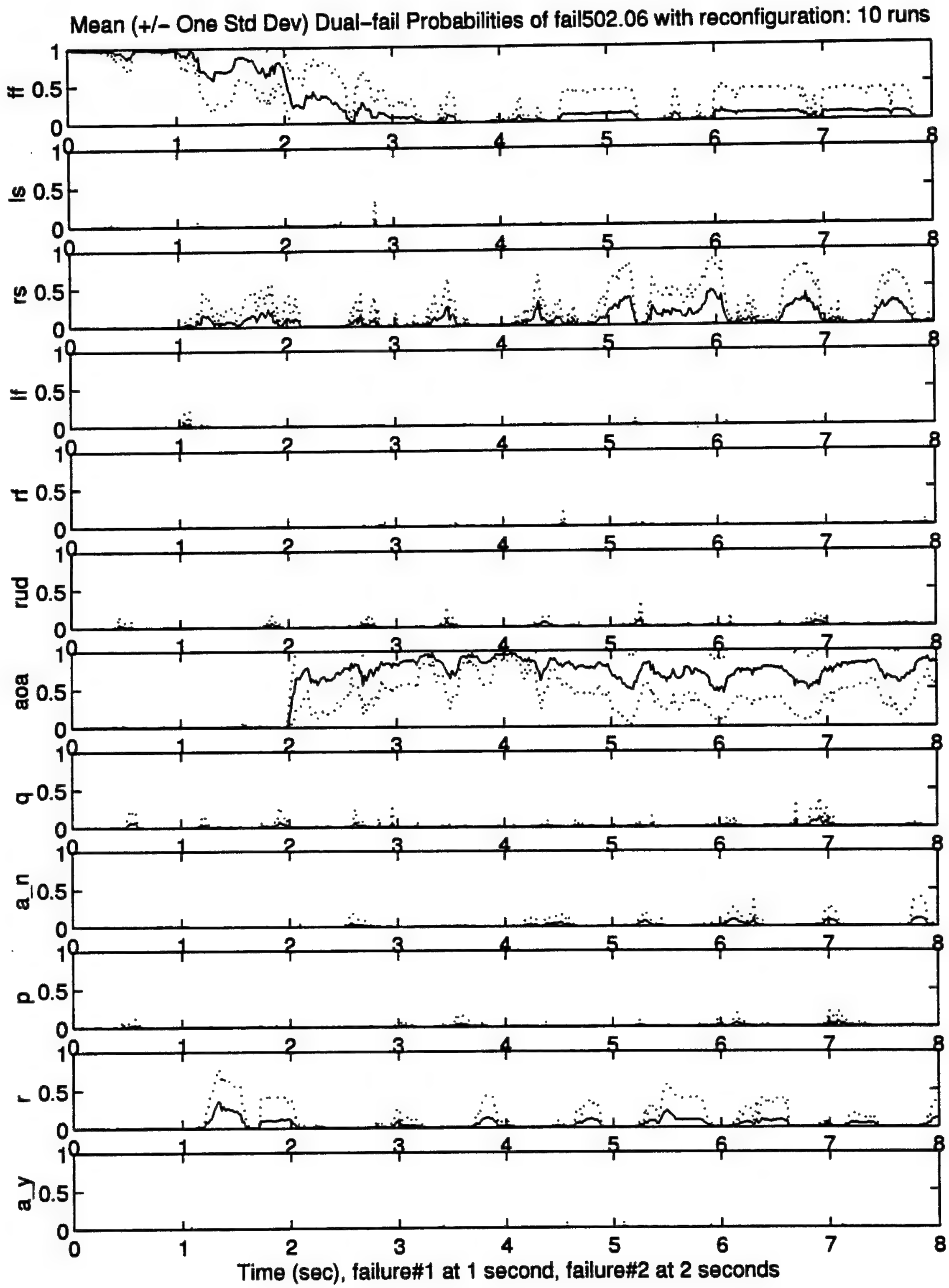
Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.503 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

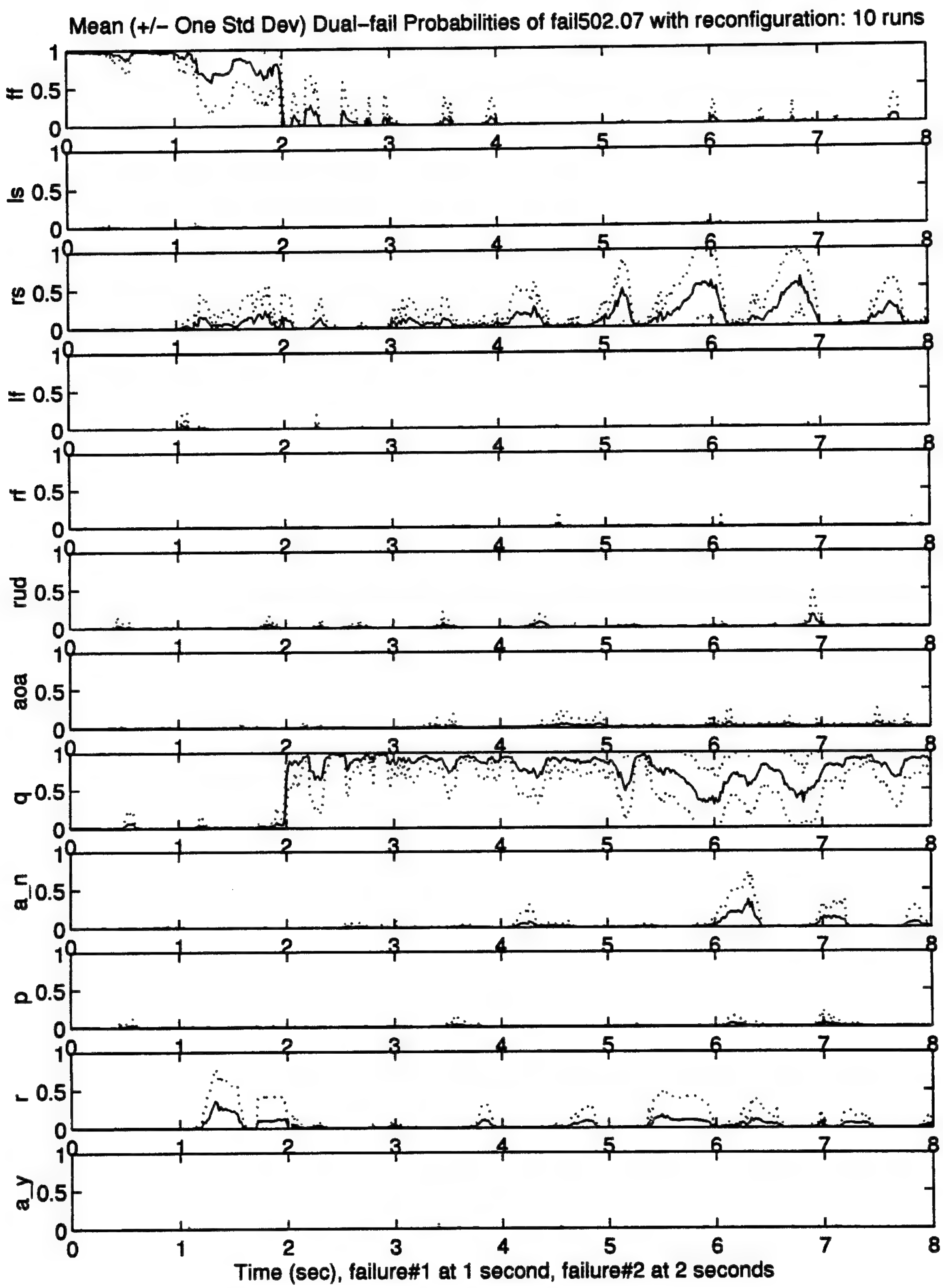


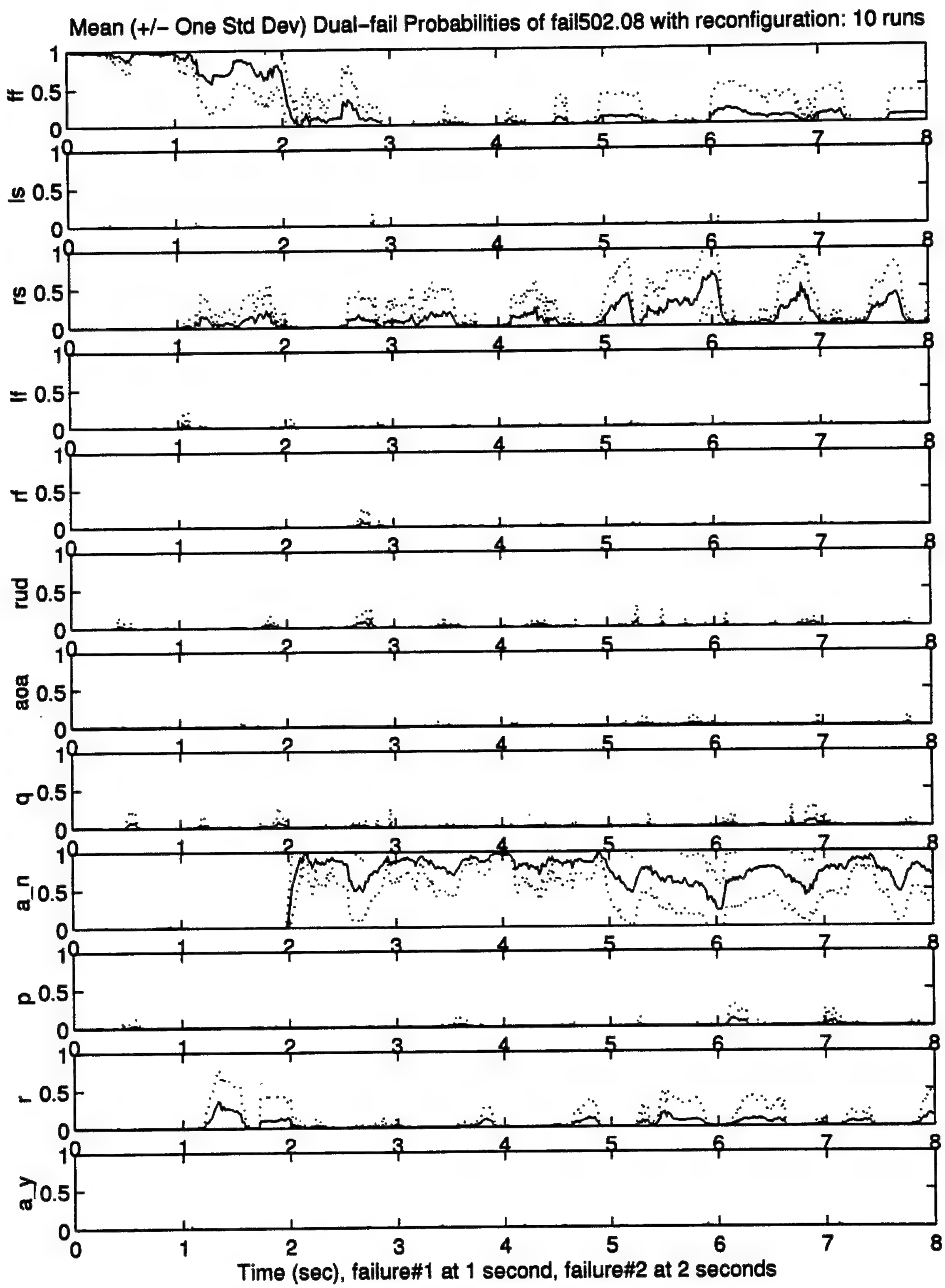
Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.504 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

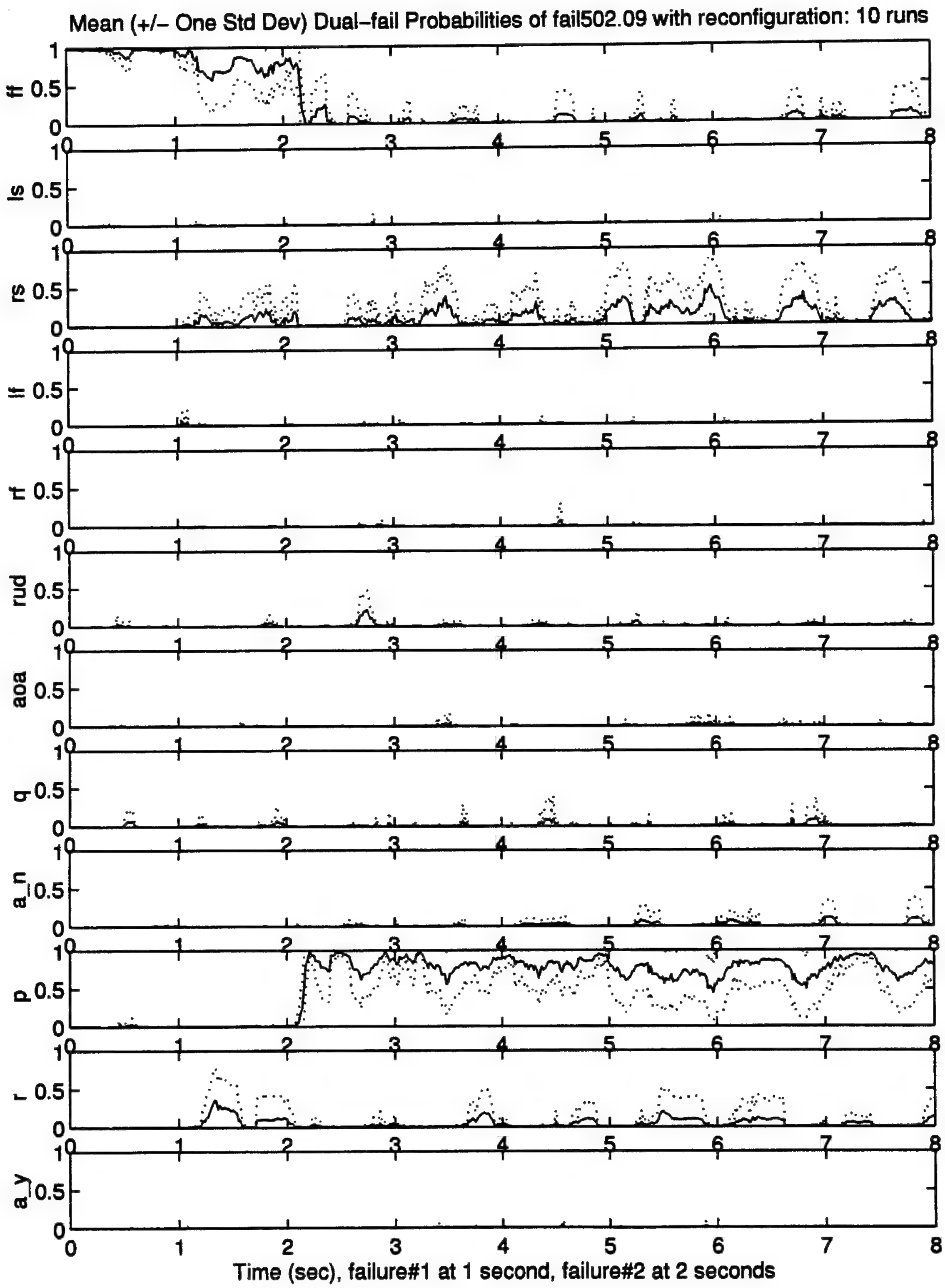


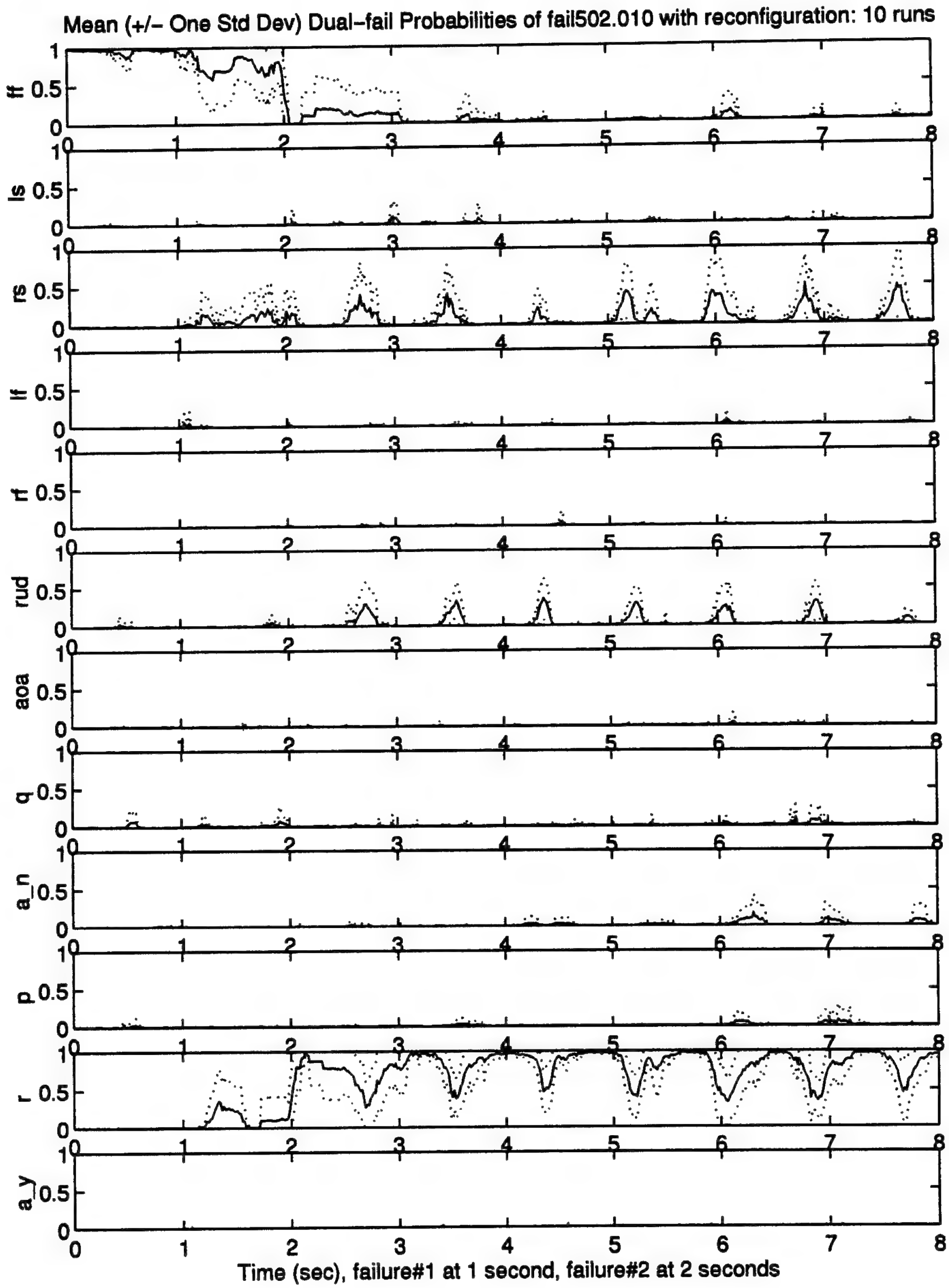
Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.505 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.06 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

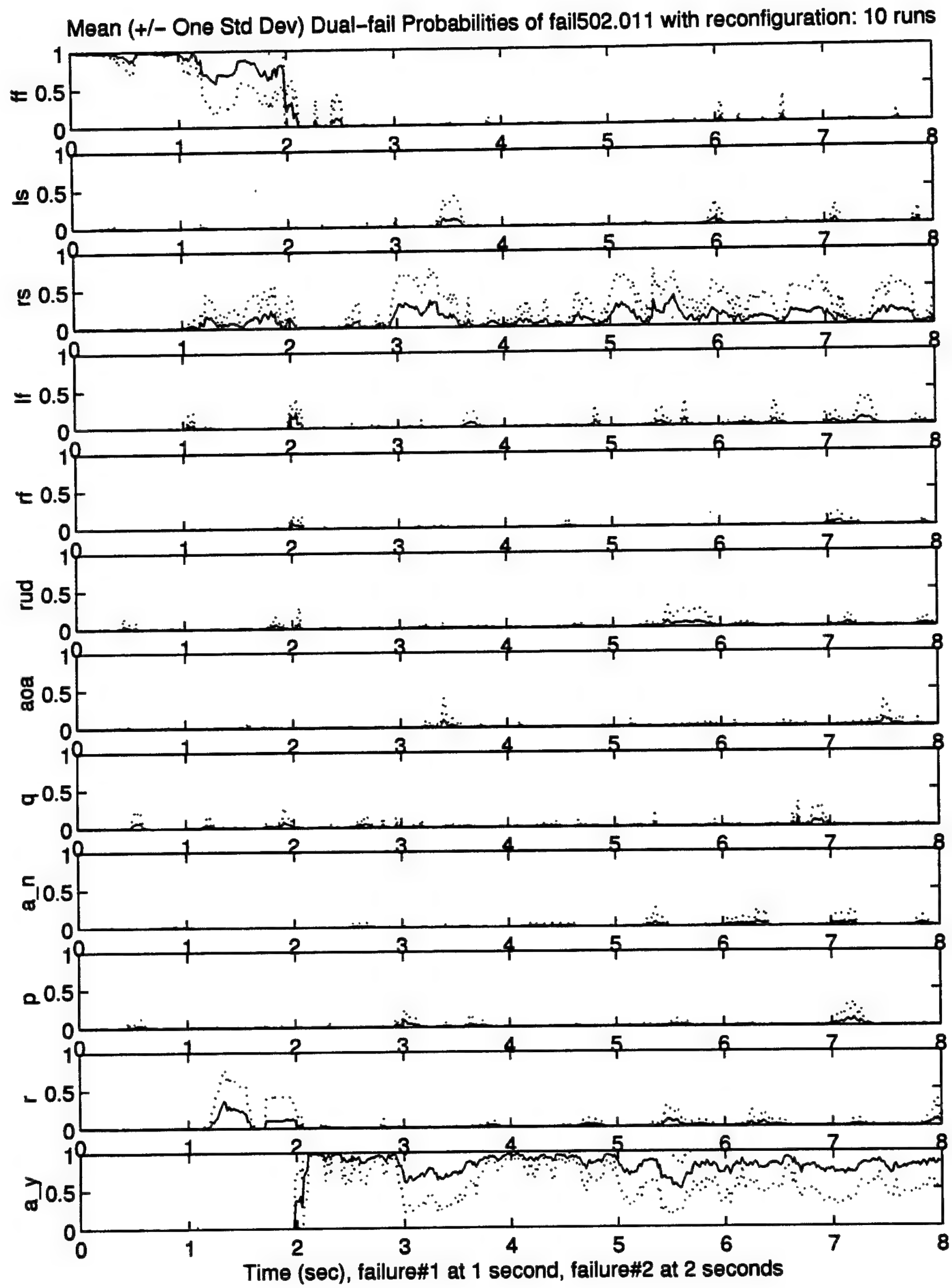

Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

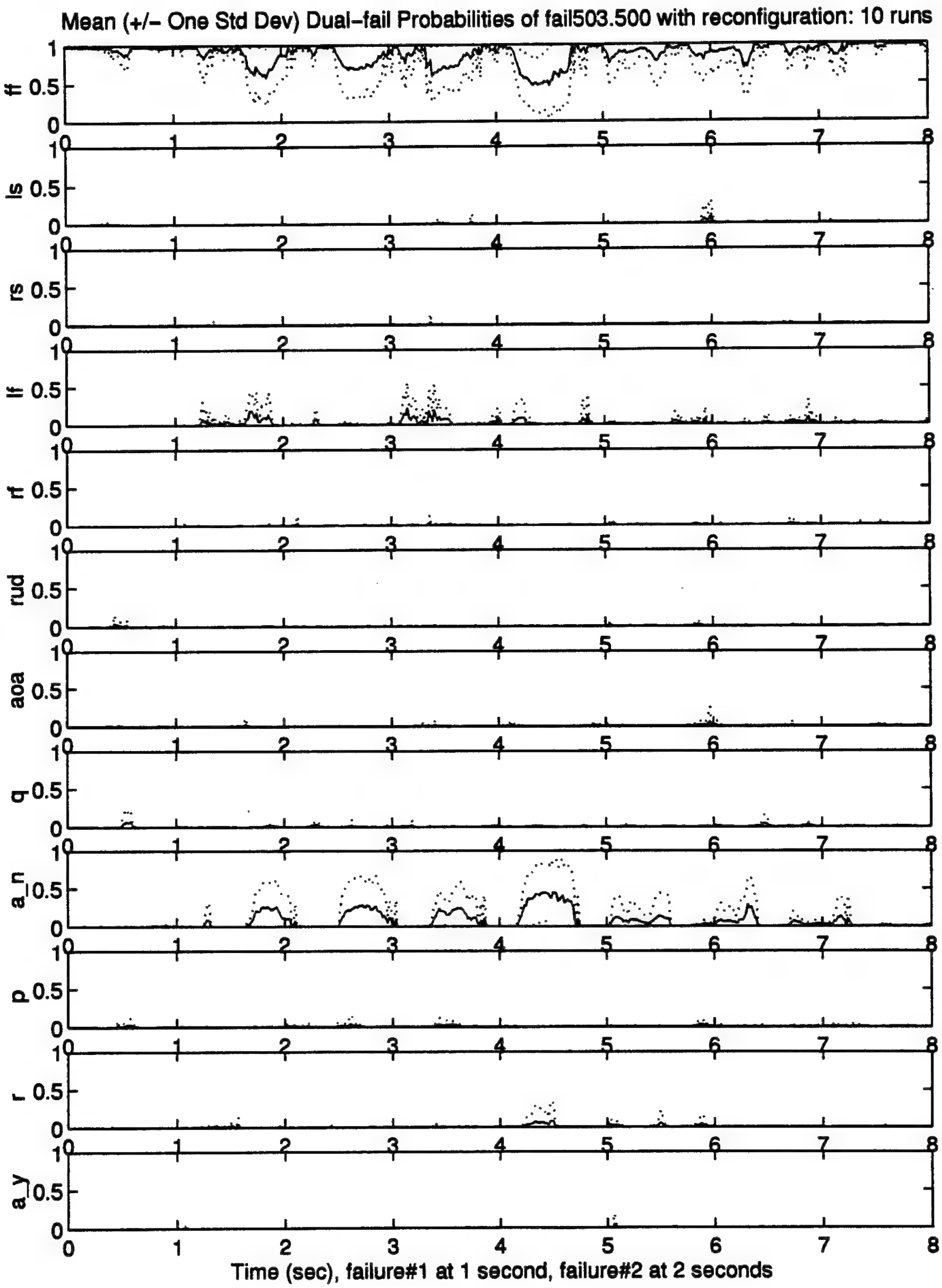

Mean (+/− One Std Dev) Dual–fail Probabilities of fail502.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0.5
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



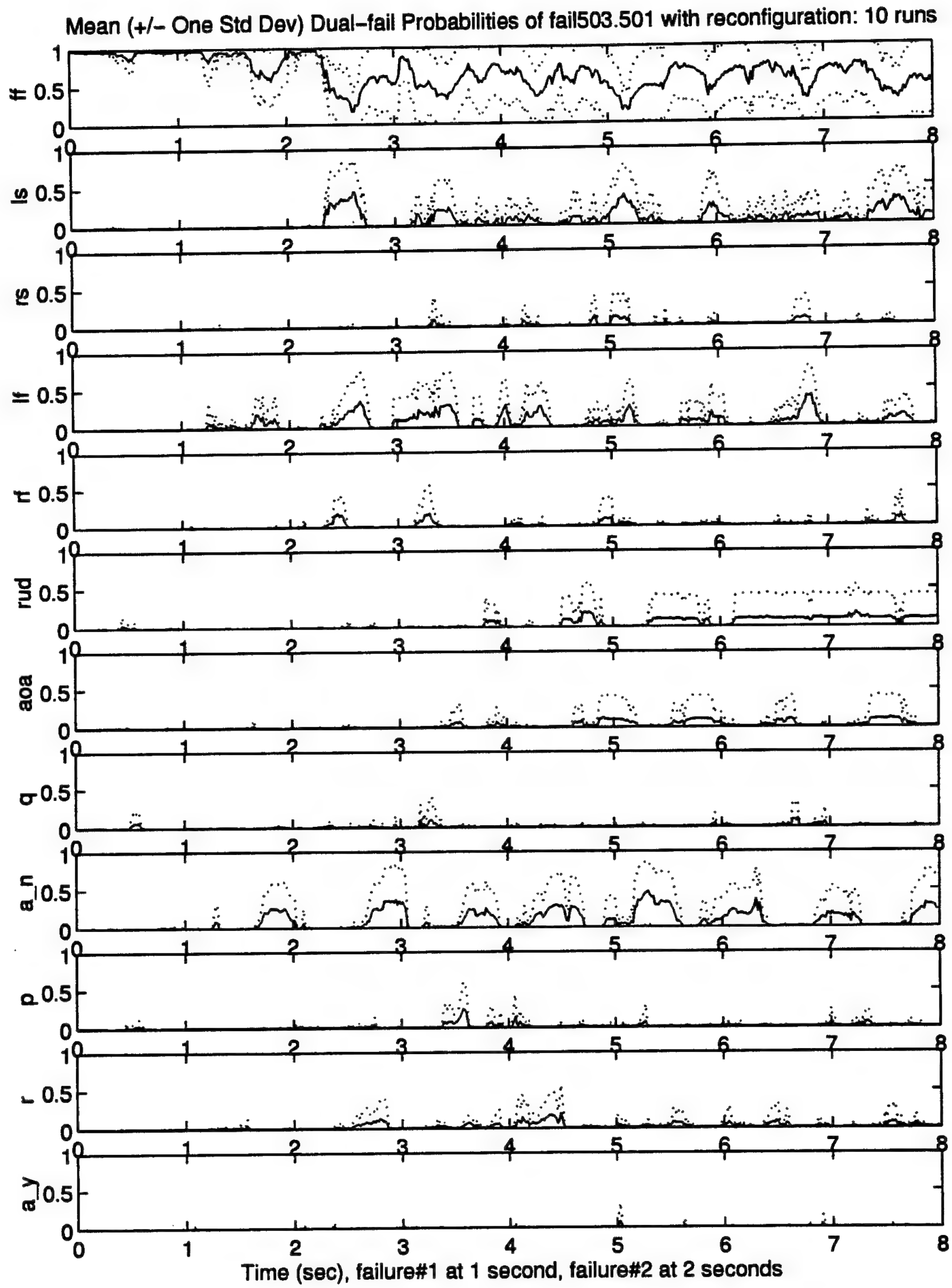
Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

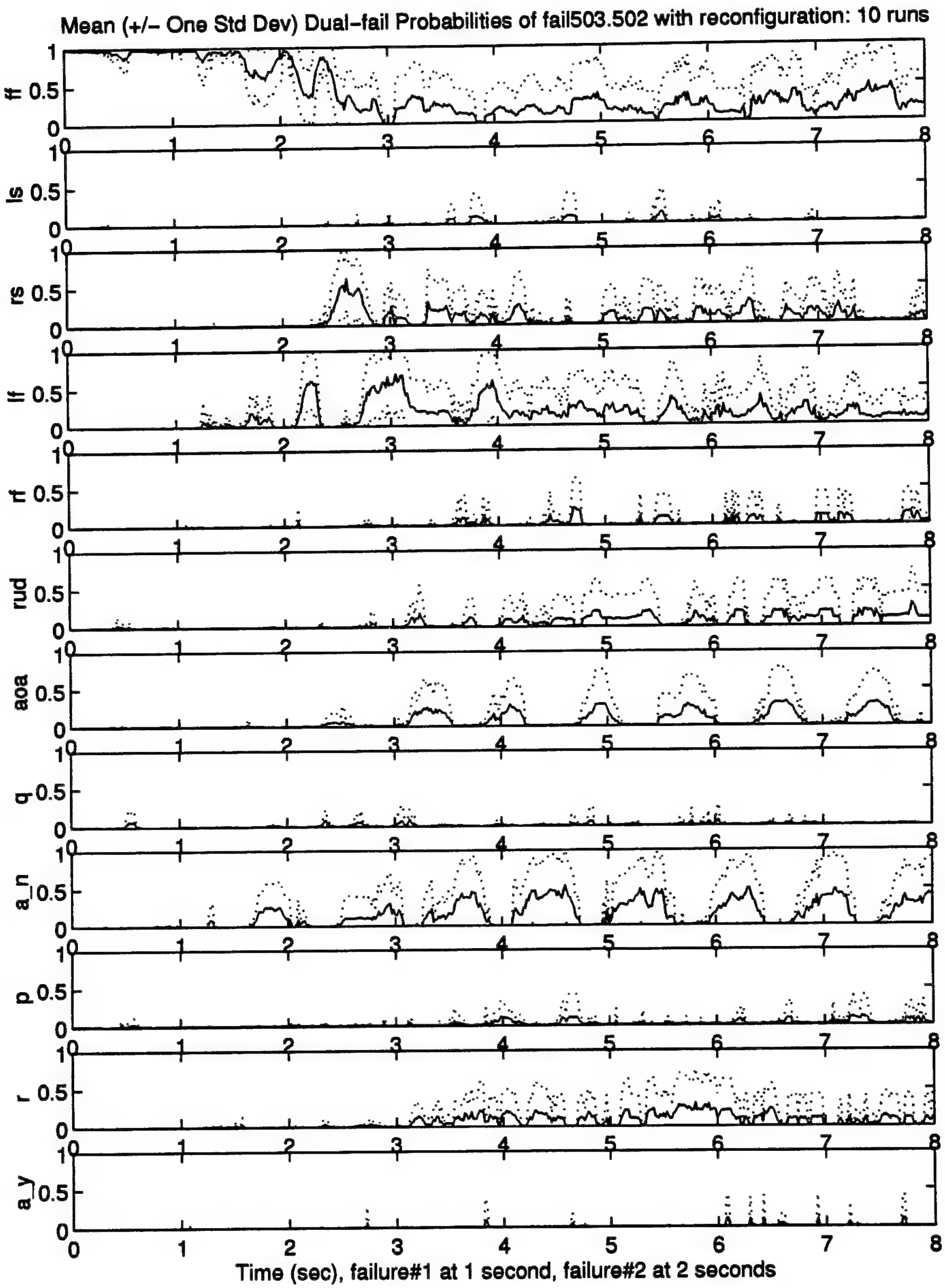


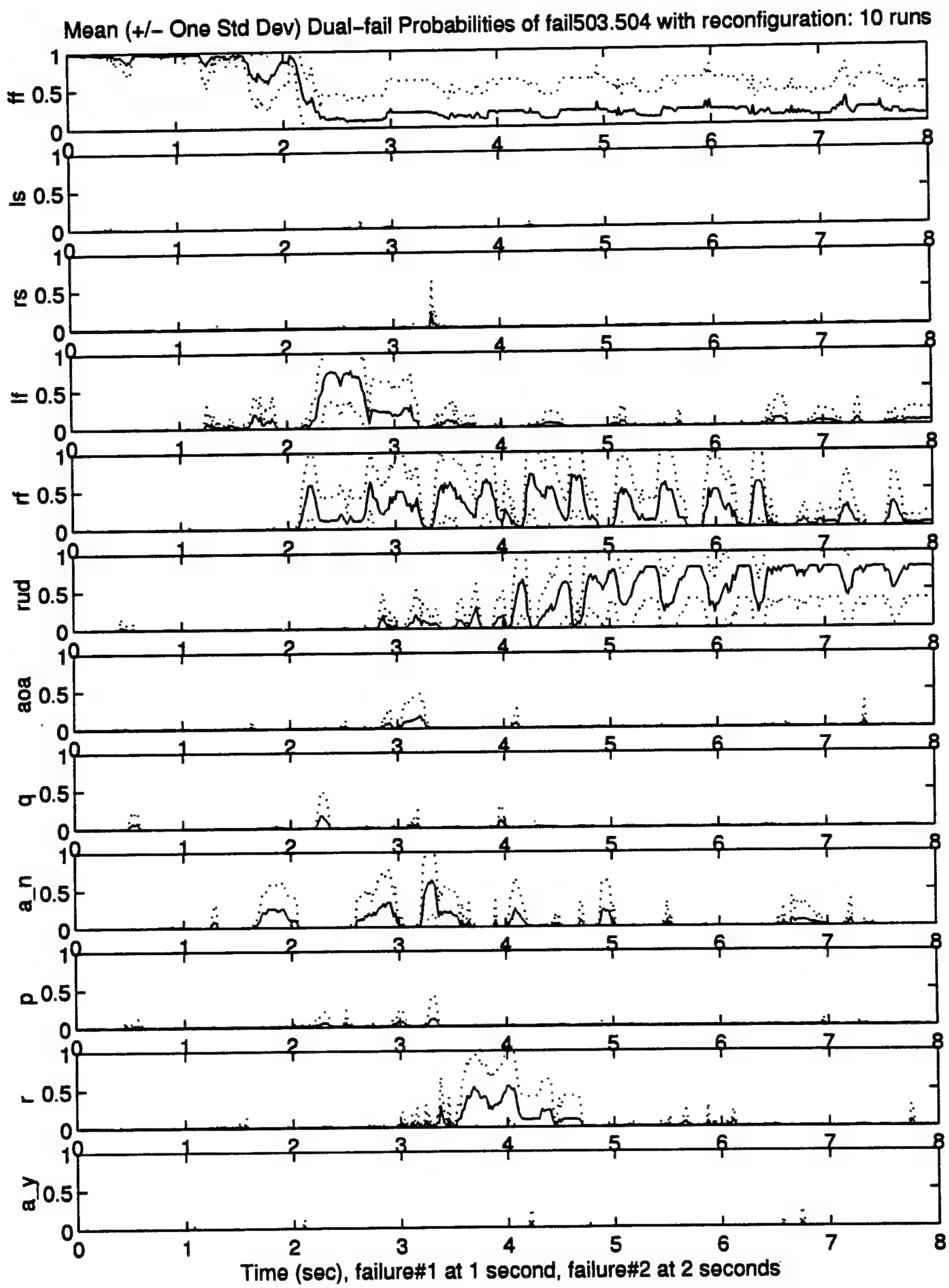
Mean (+/- One Std Dev) Dual-fail Probabilities of fail502.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



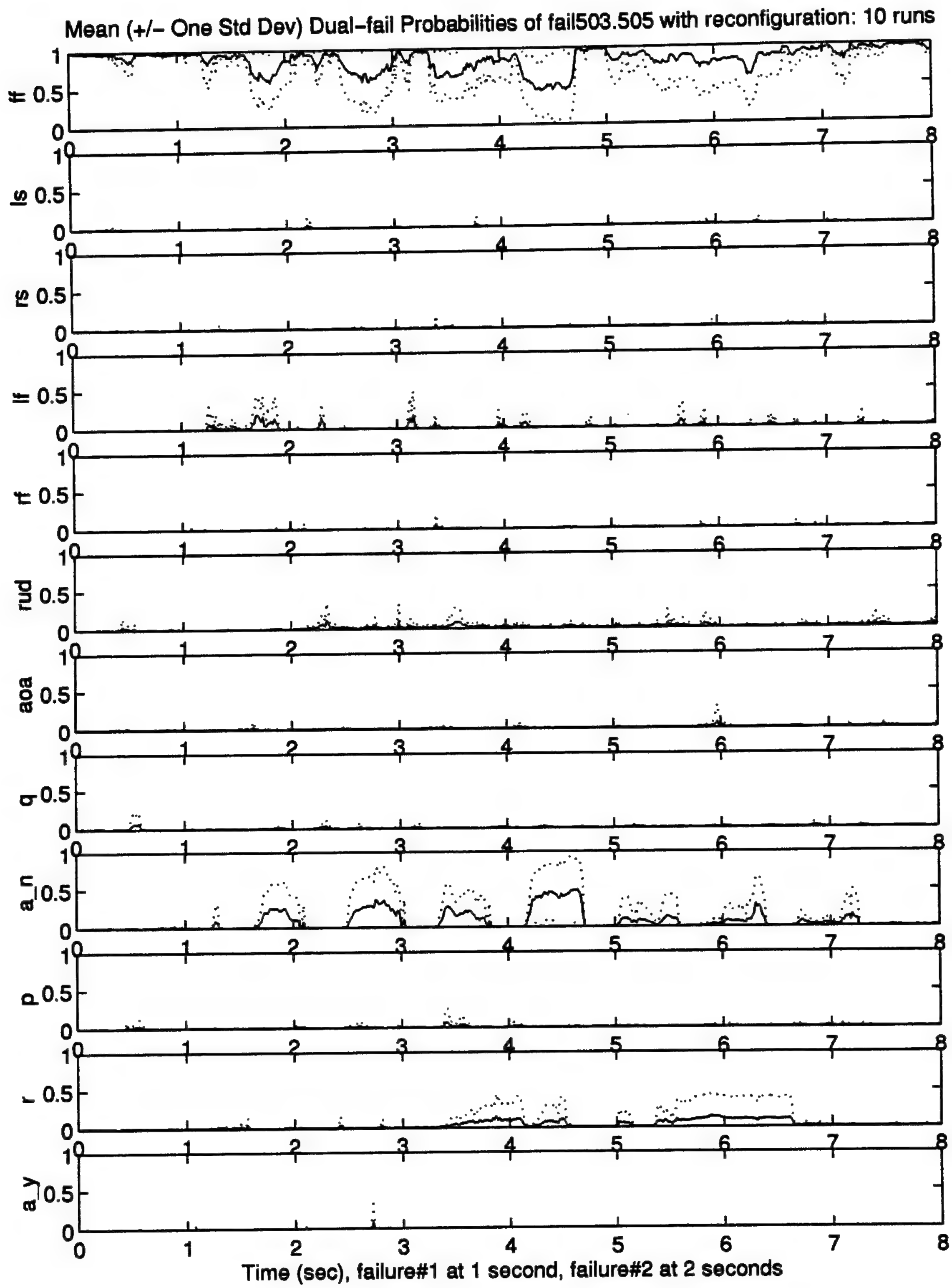
Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.500 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

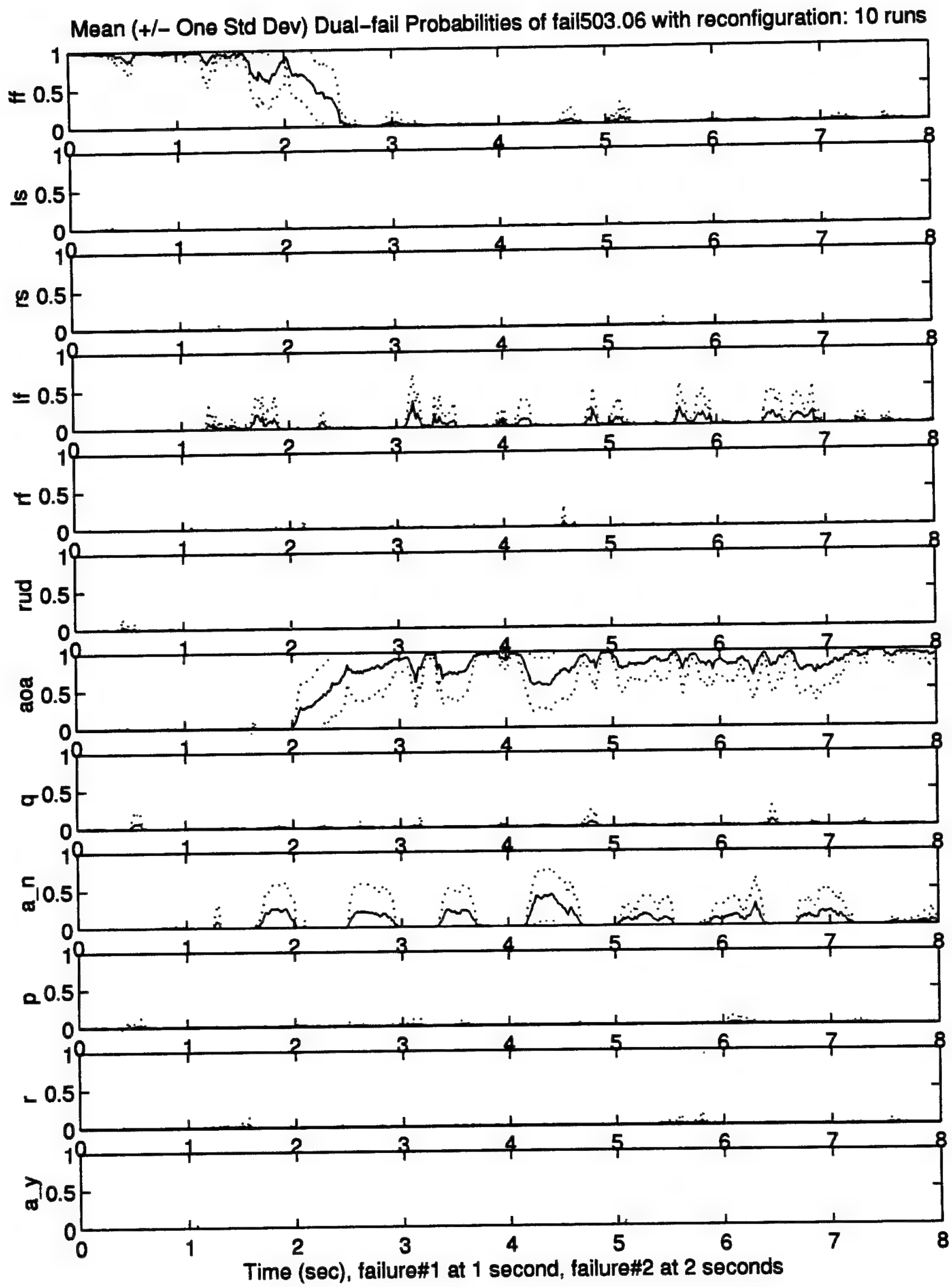

Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.501 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.502 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

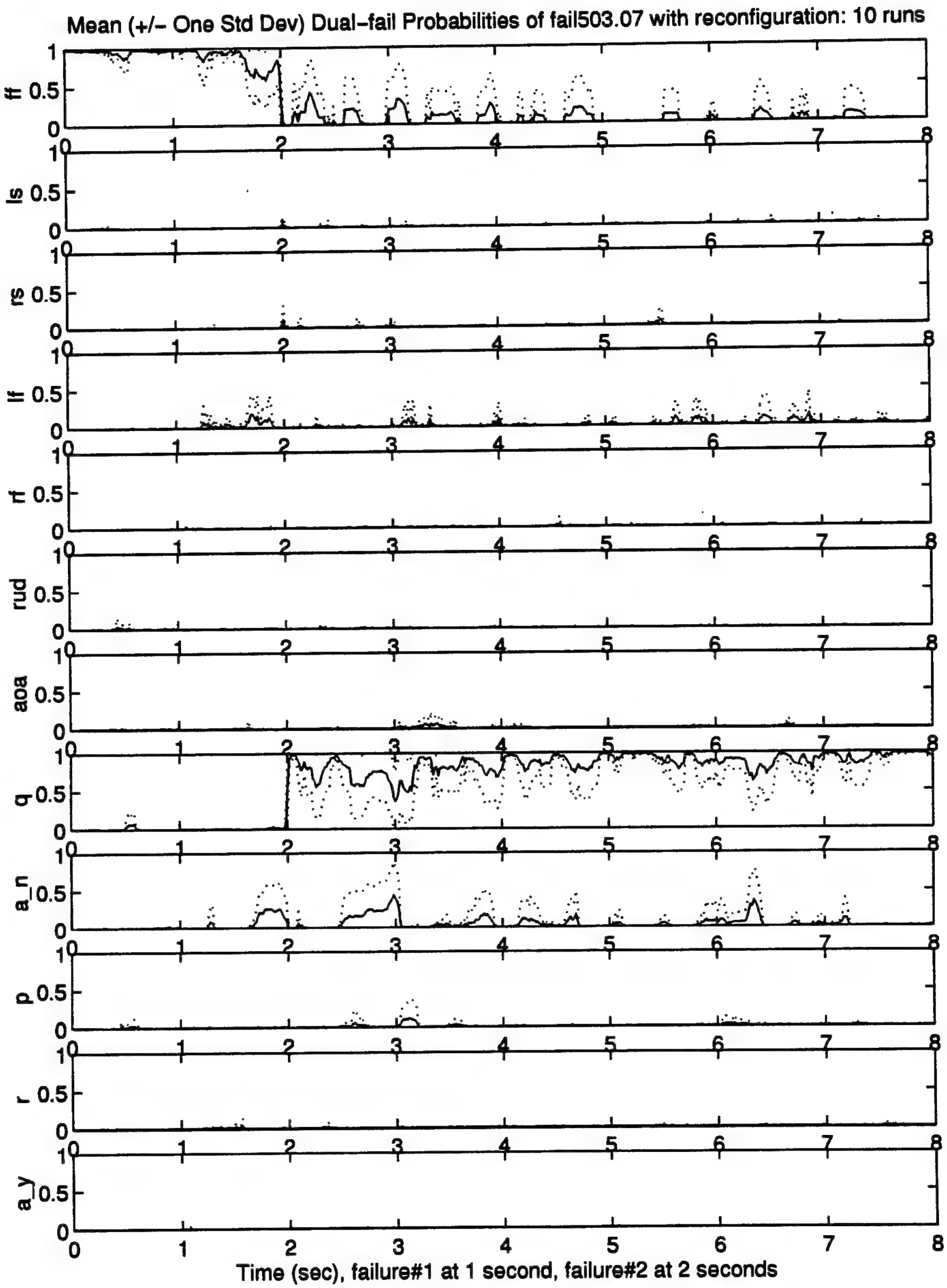


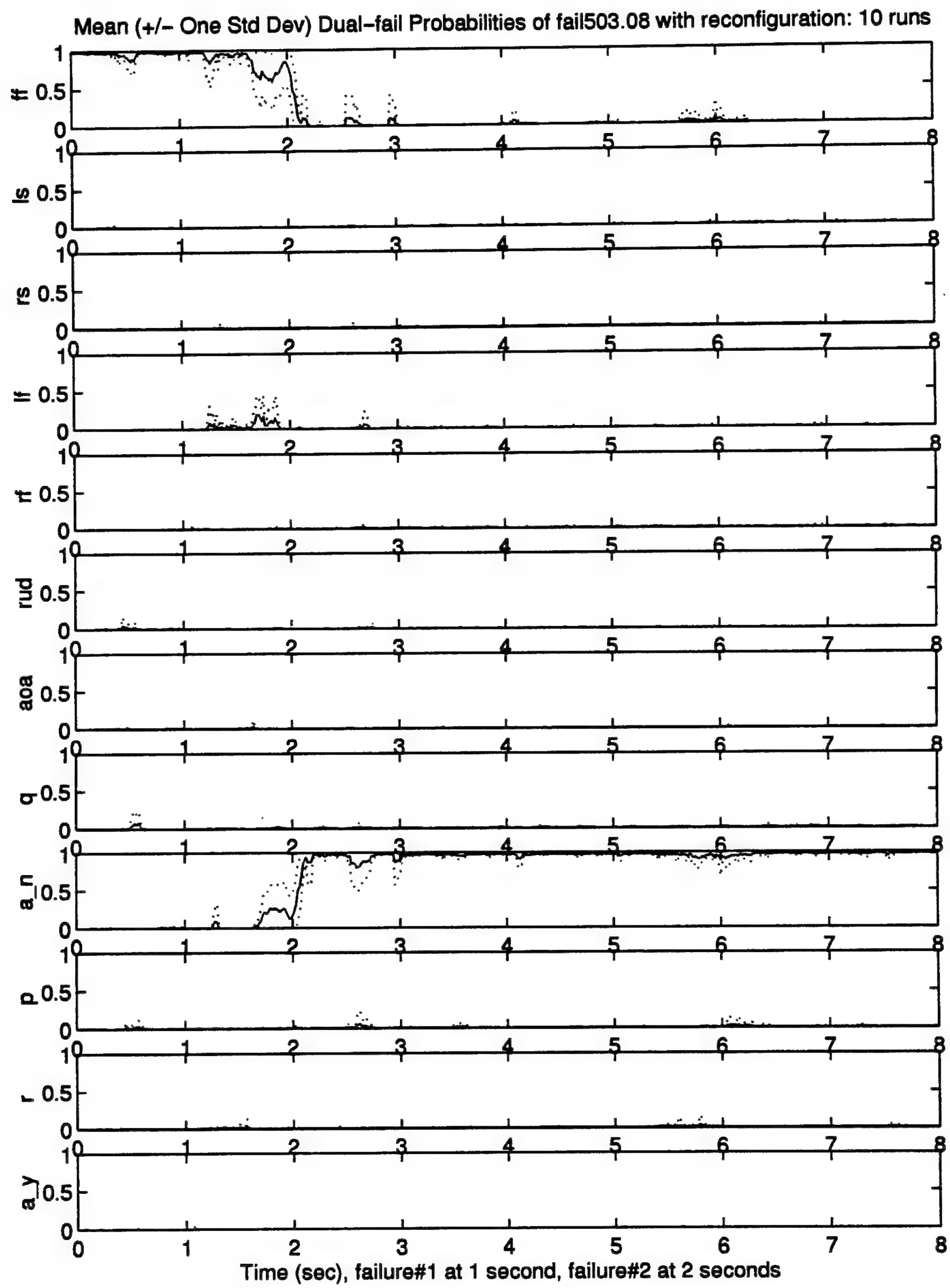
Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.504 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

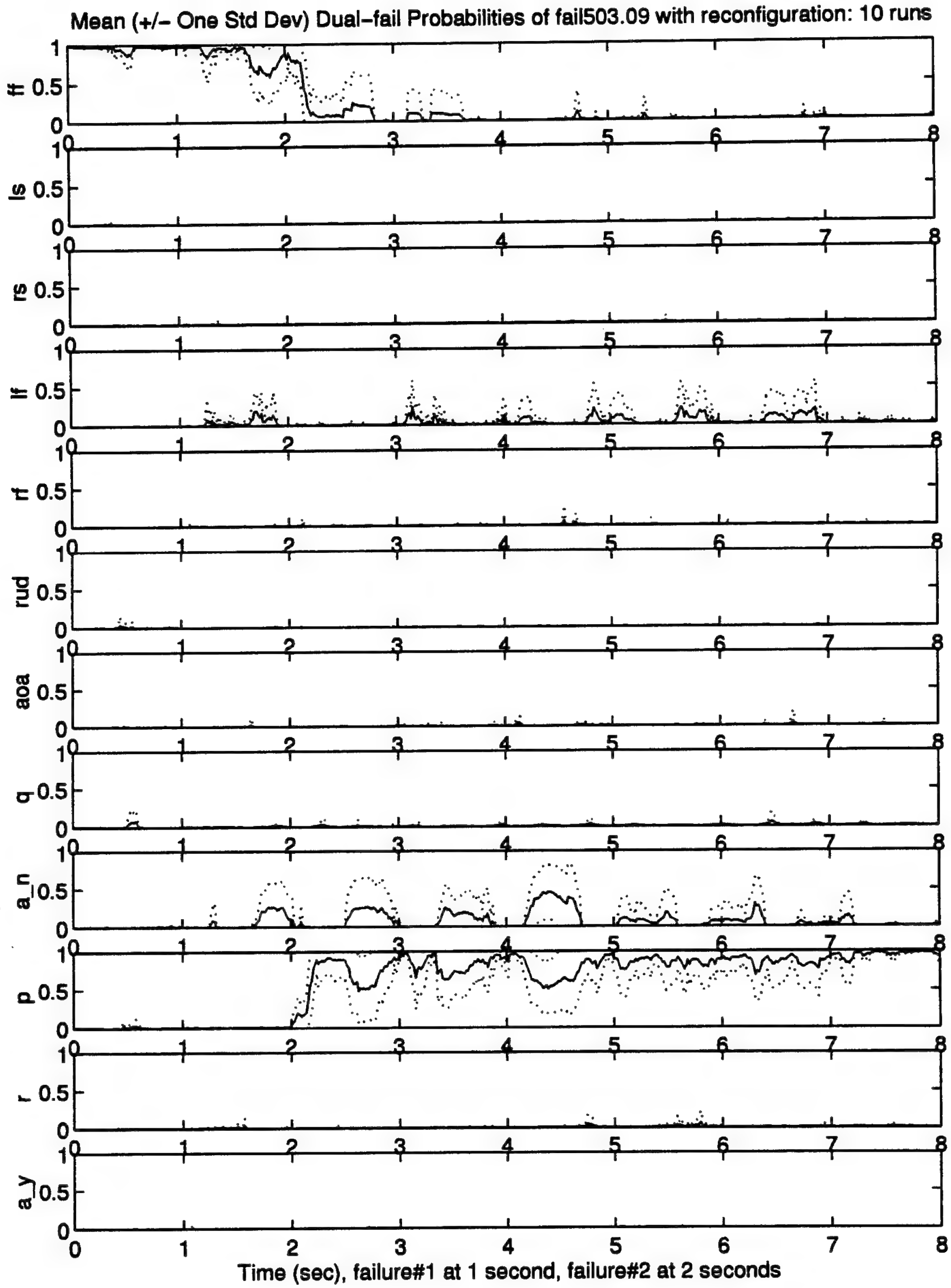

Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.505 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

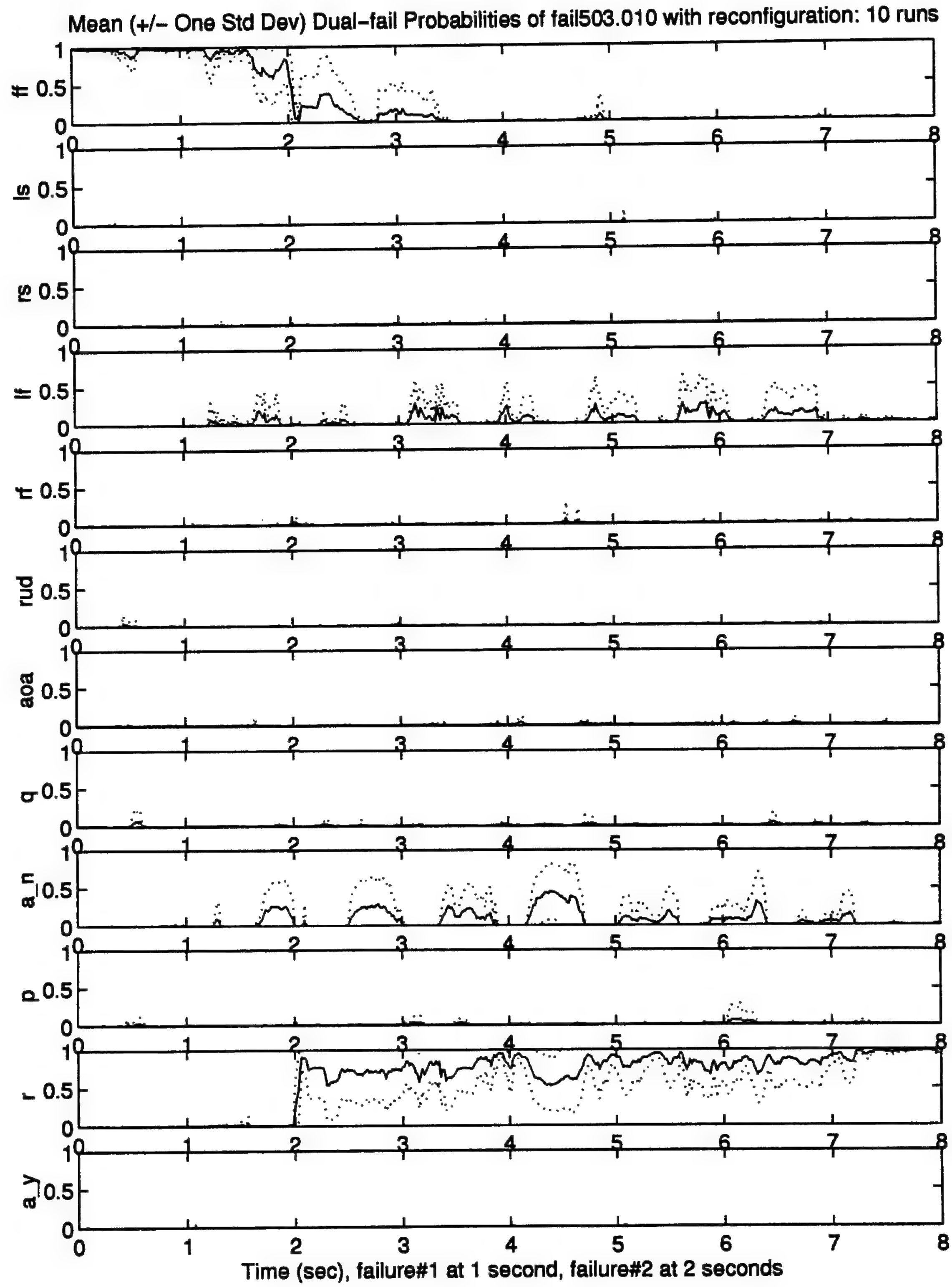


Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.06 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

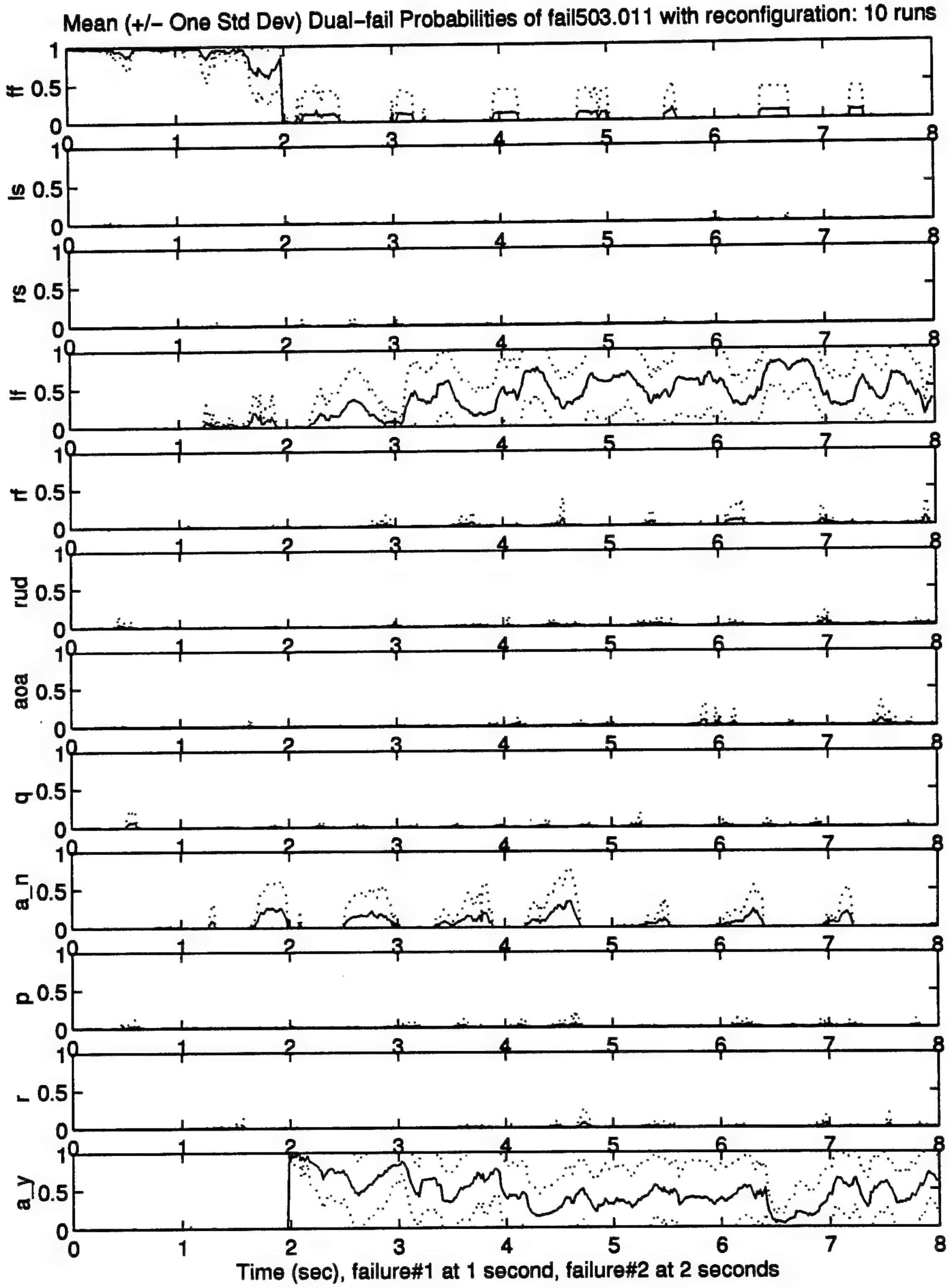

Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

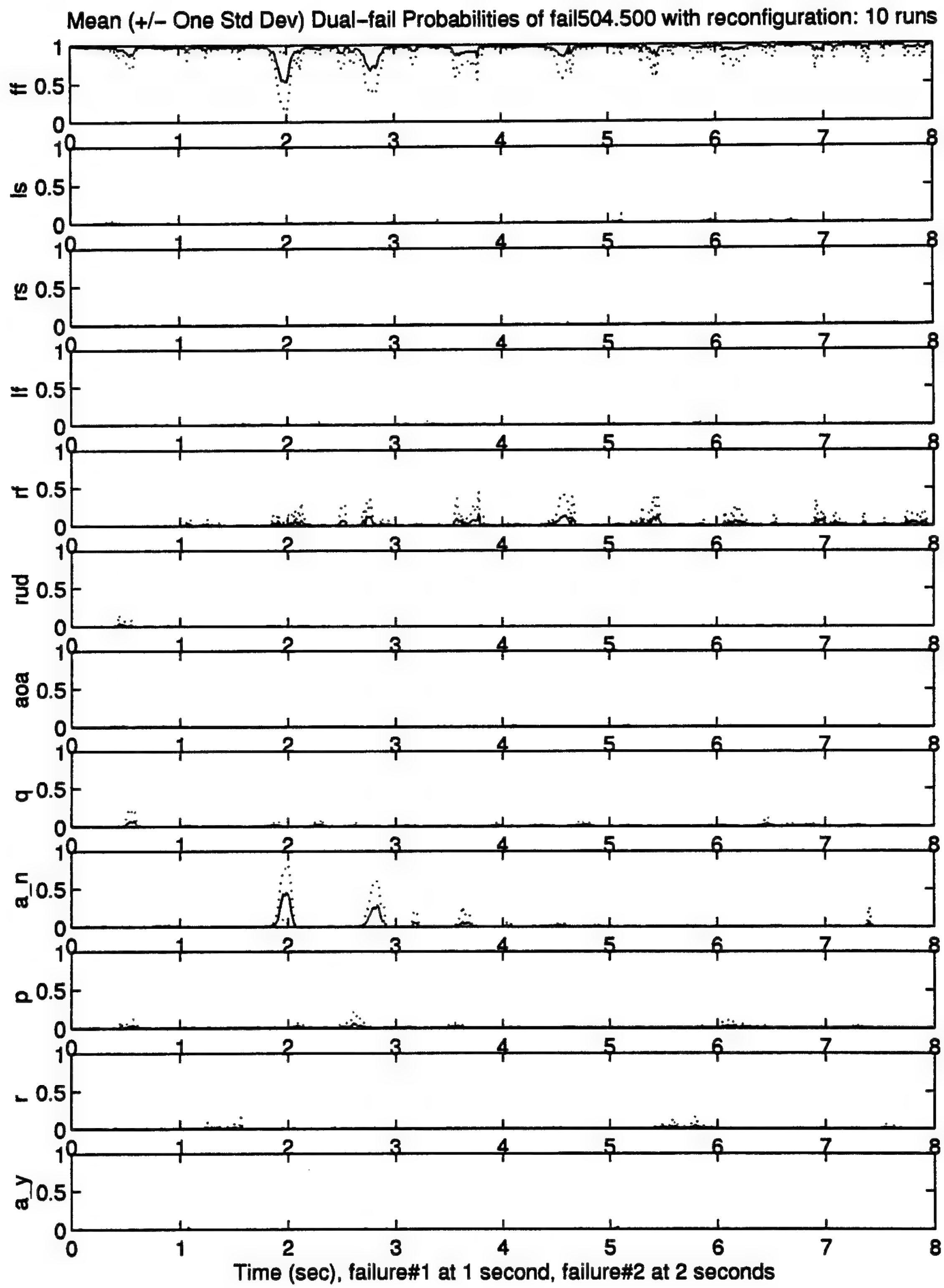

Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

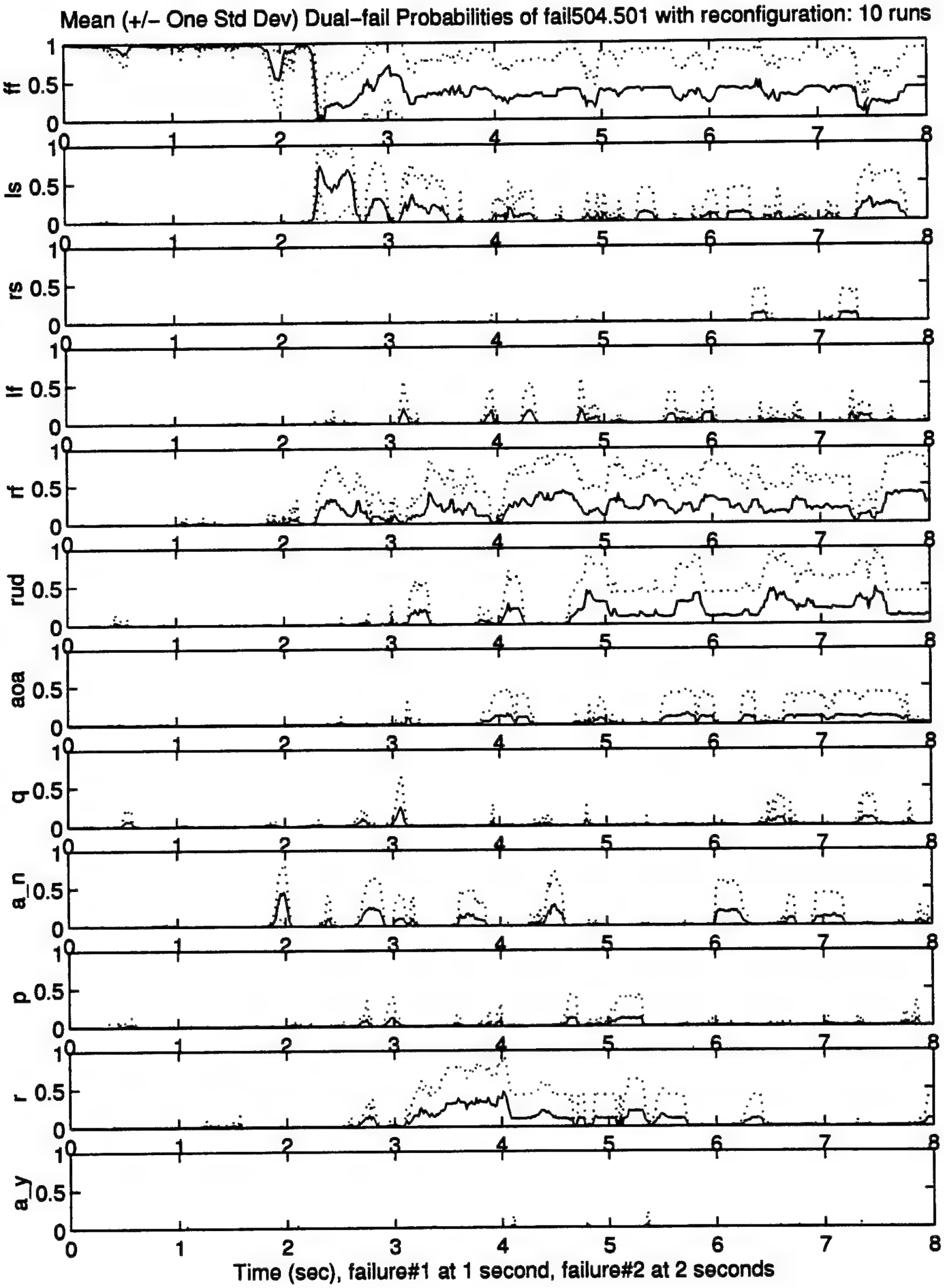

Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



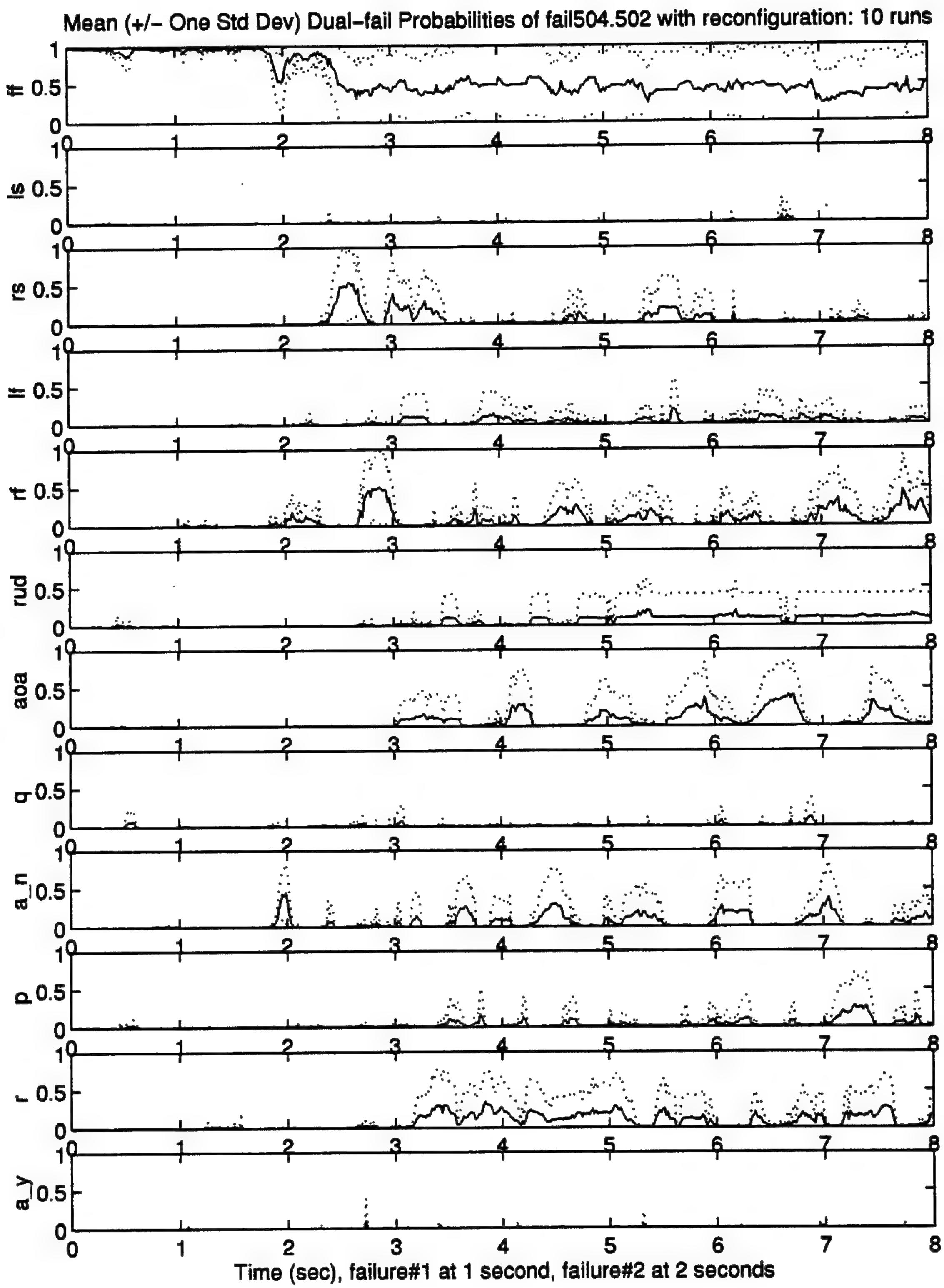
Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

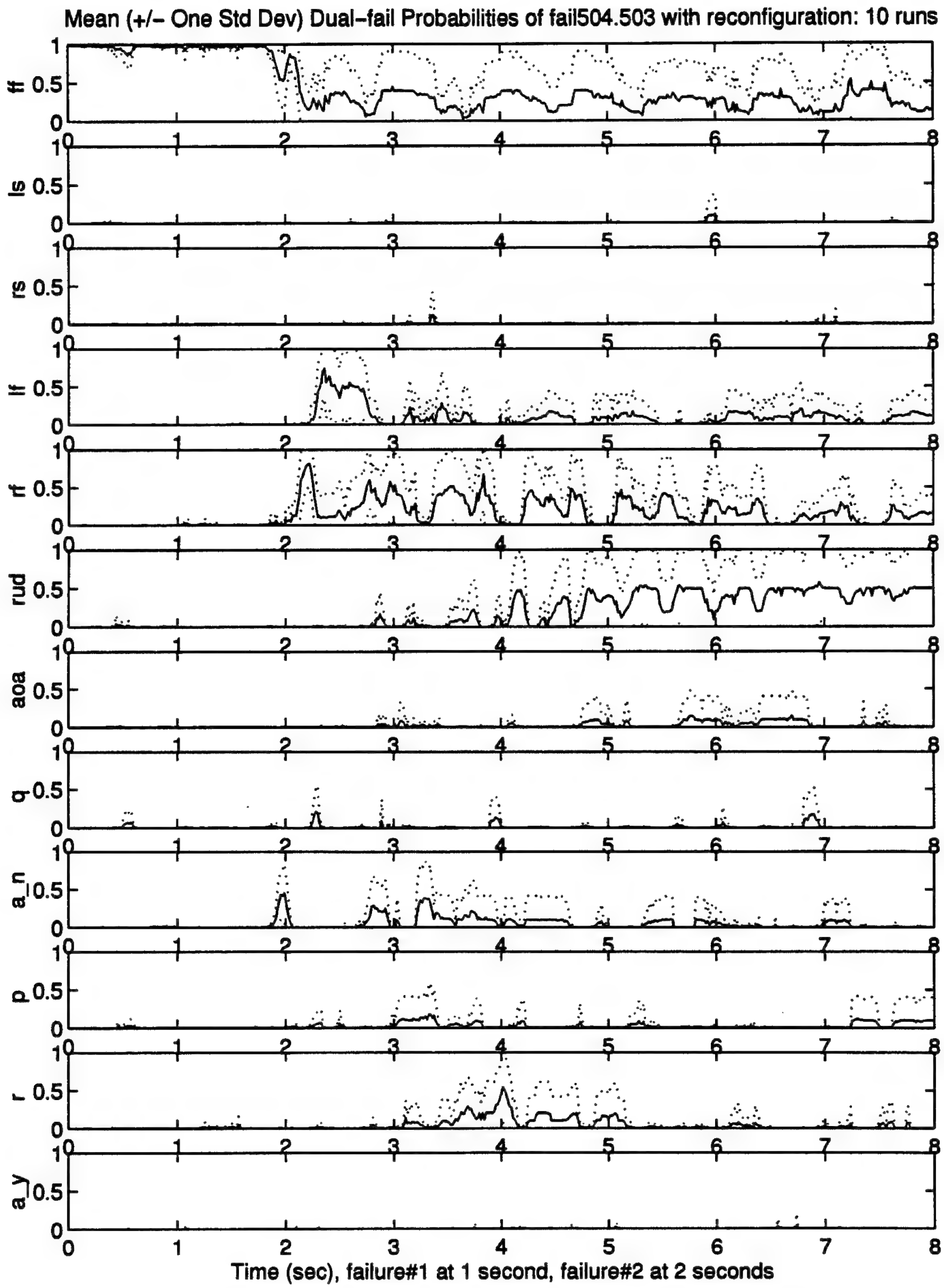

Mean (+/- One Std Dev) Dual-fail Probabilities of fail503.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

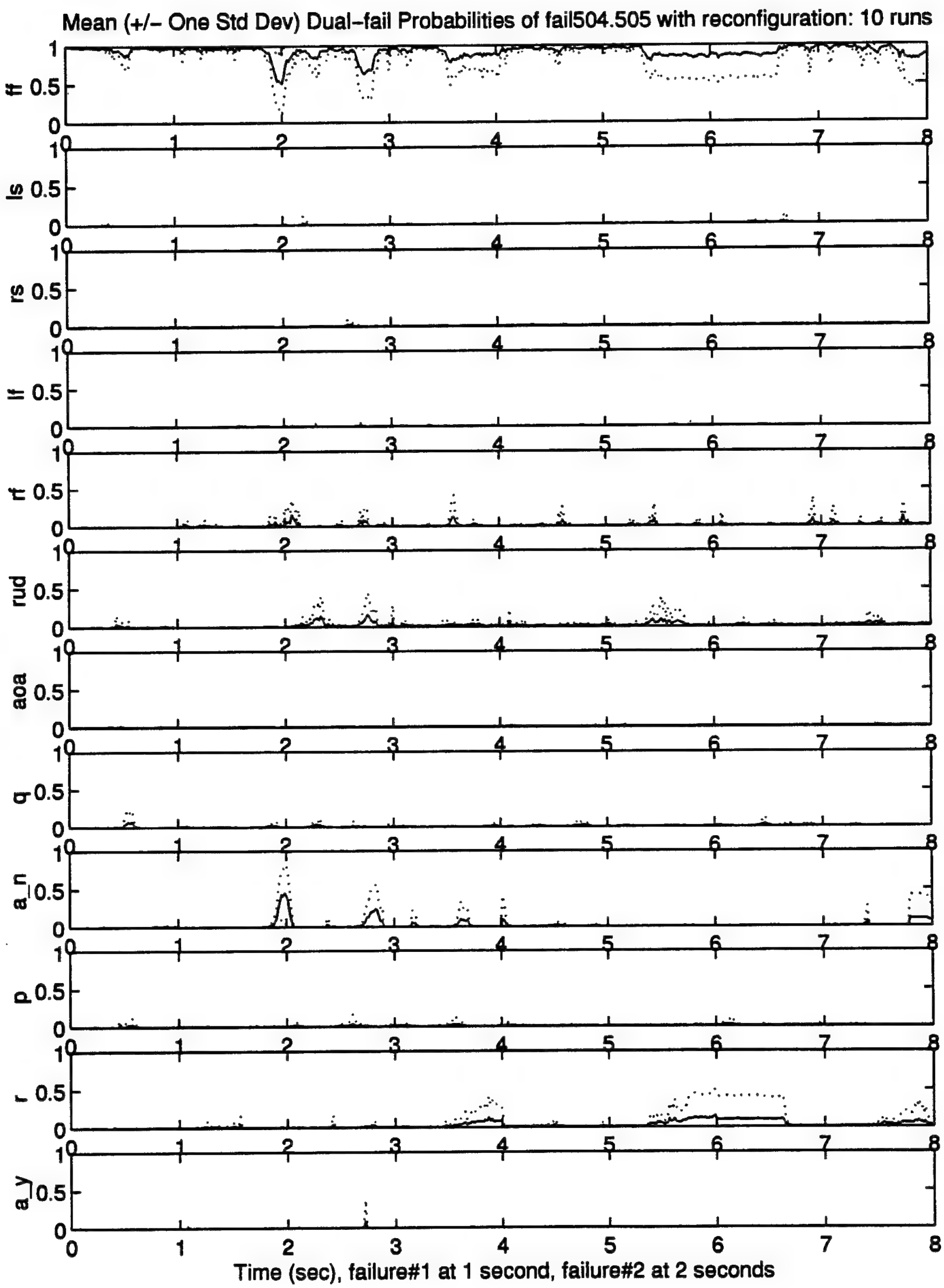

Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.500 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



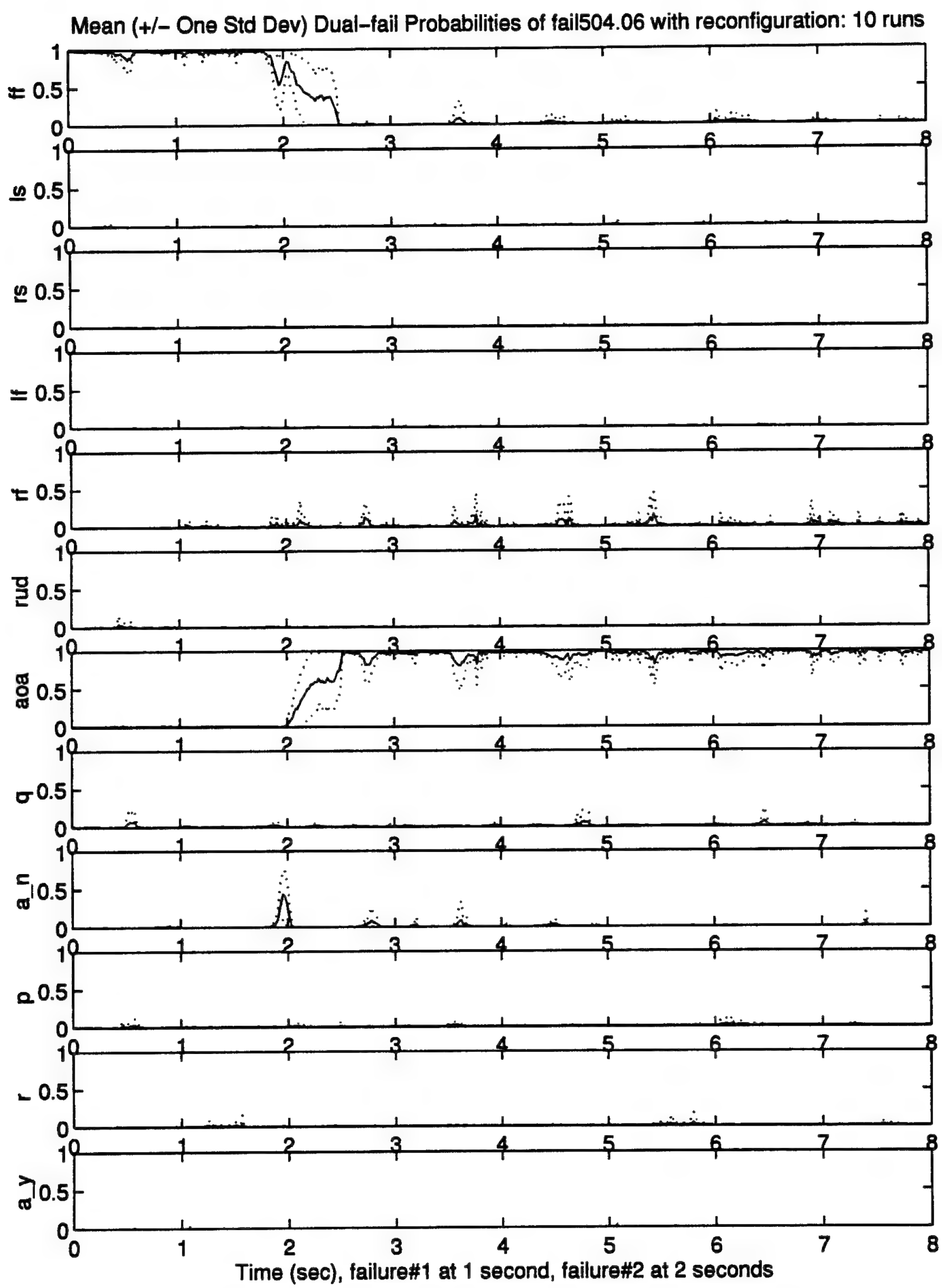
Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.501 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.502 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

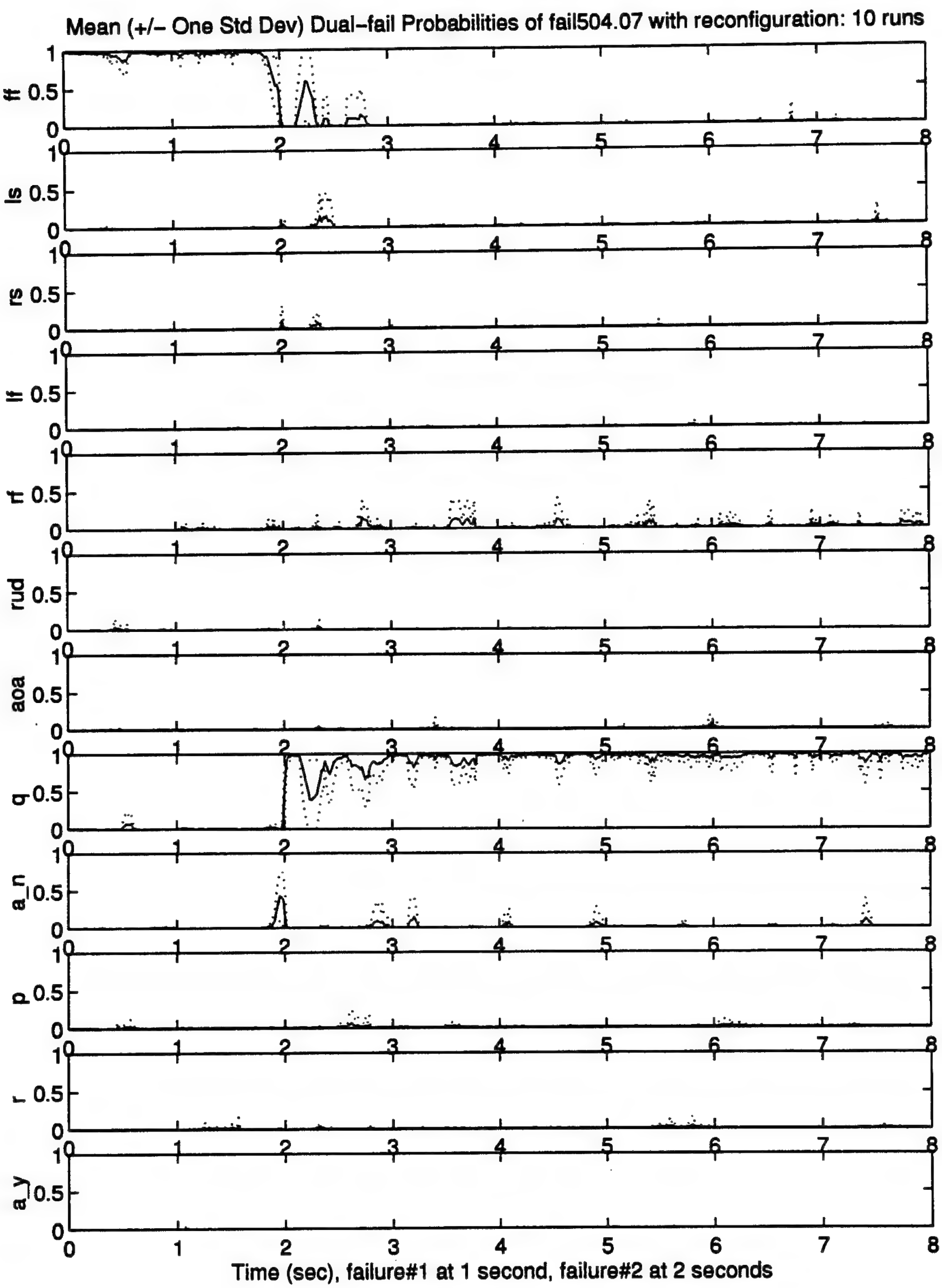

Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.503 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

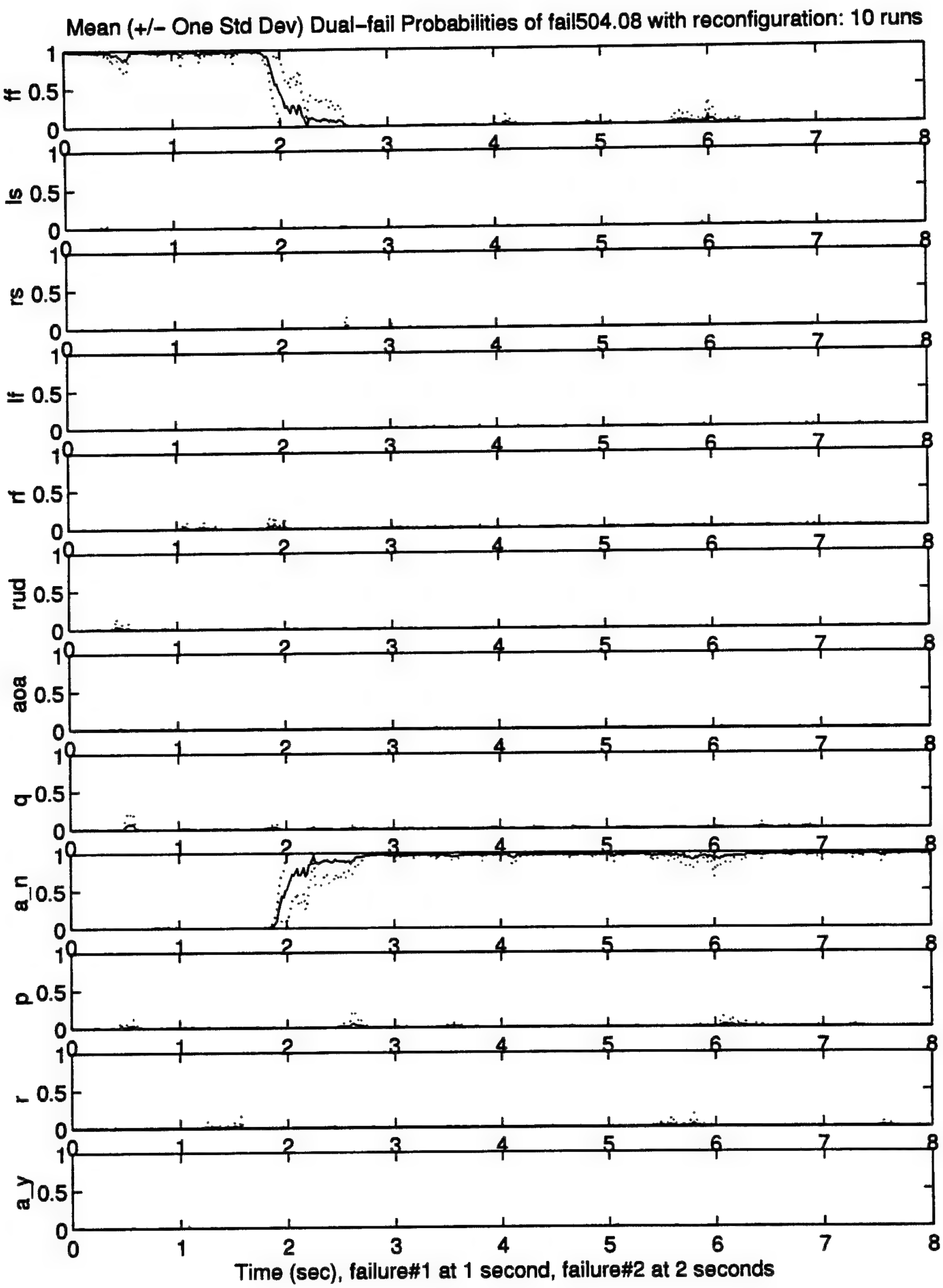


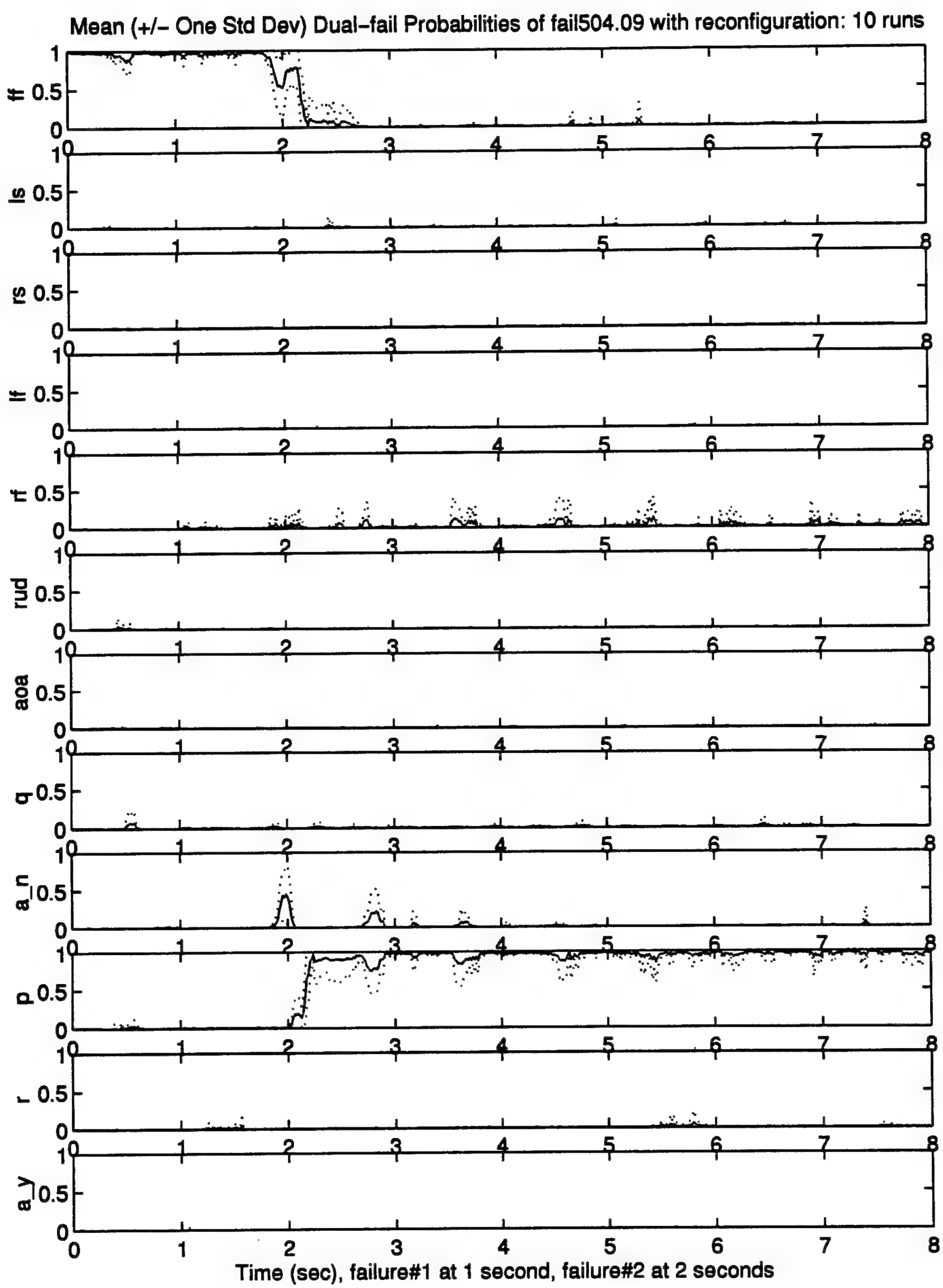
Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.505 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

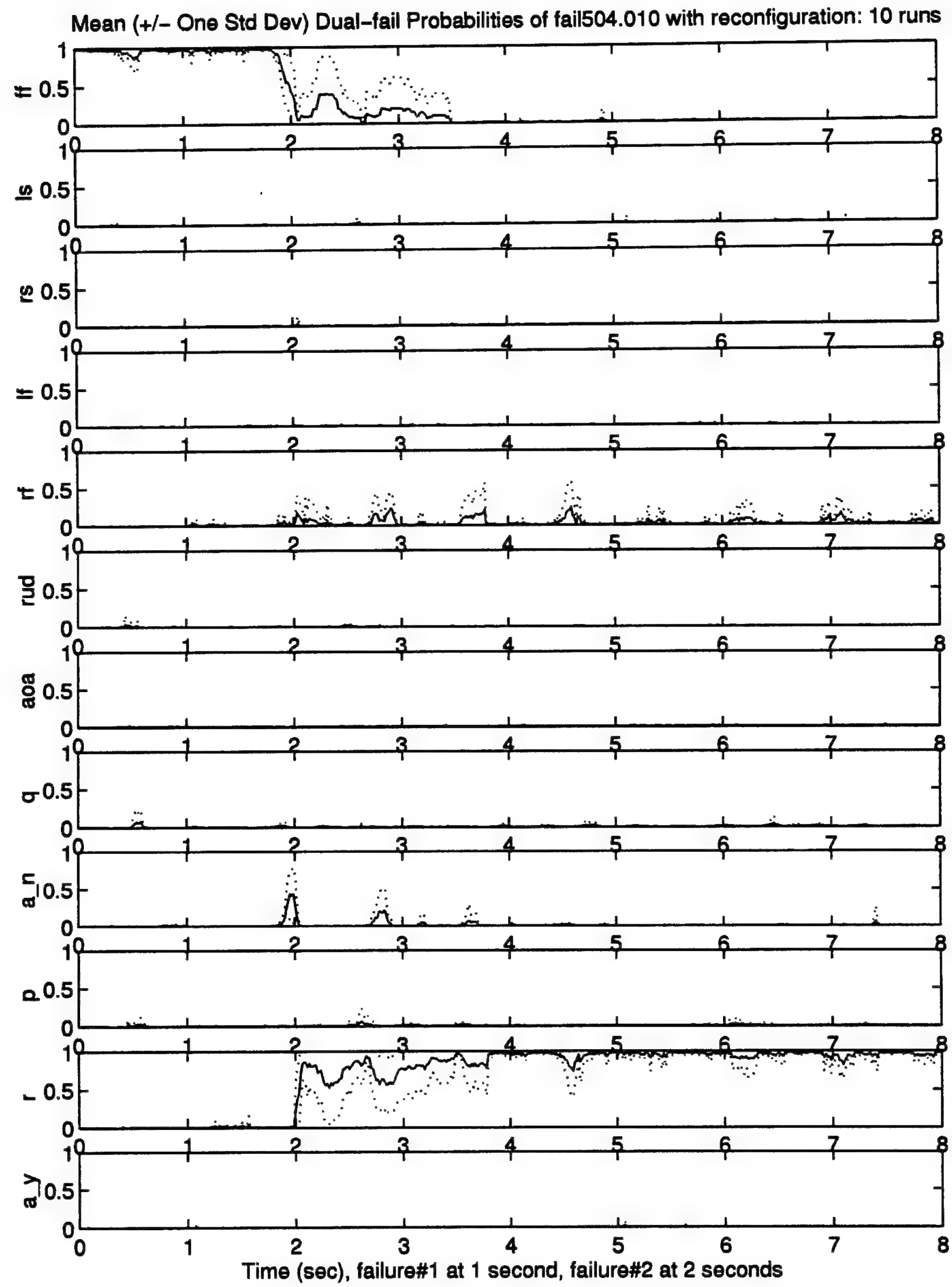


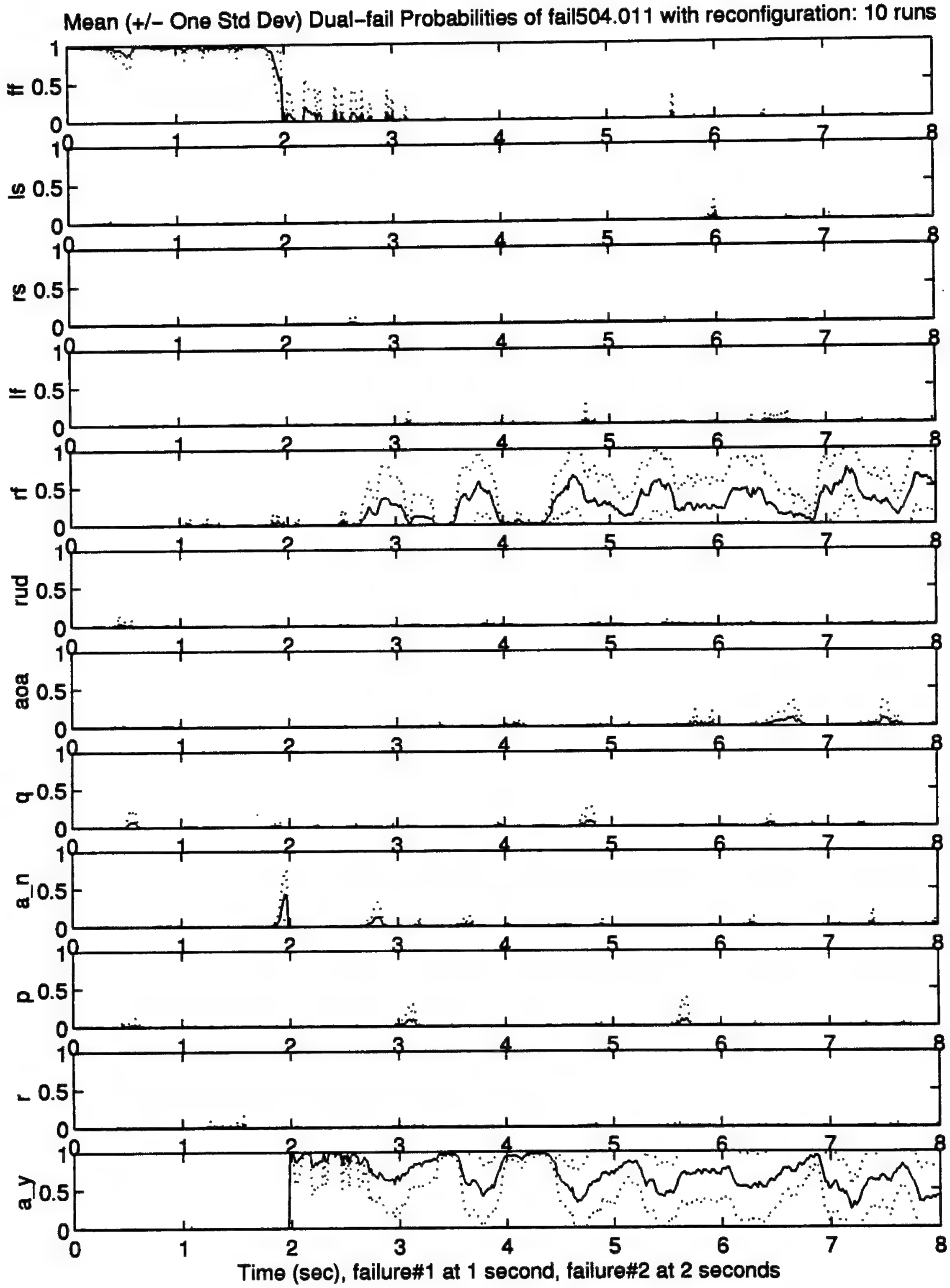
Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.06 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

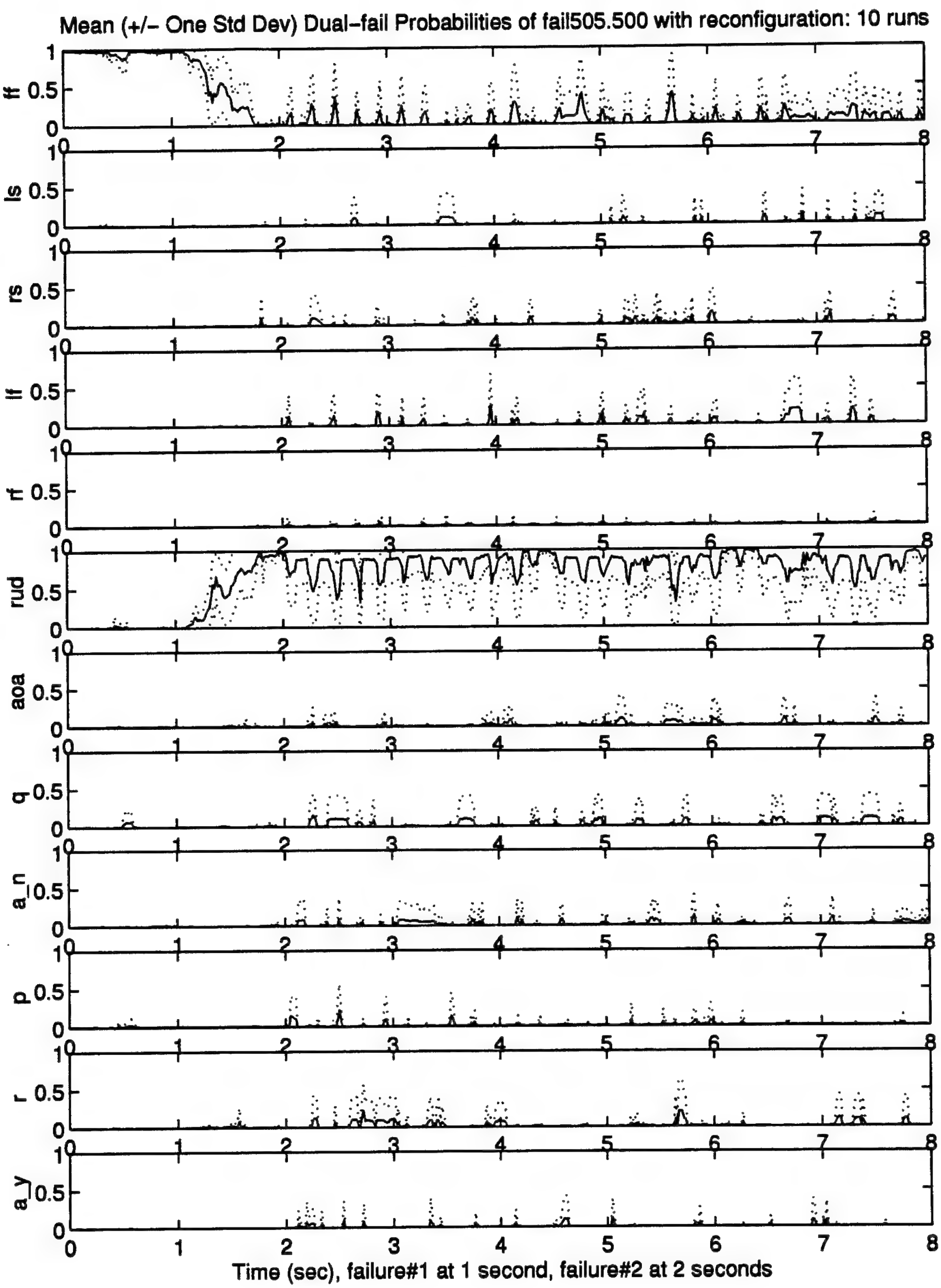

Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

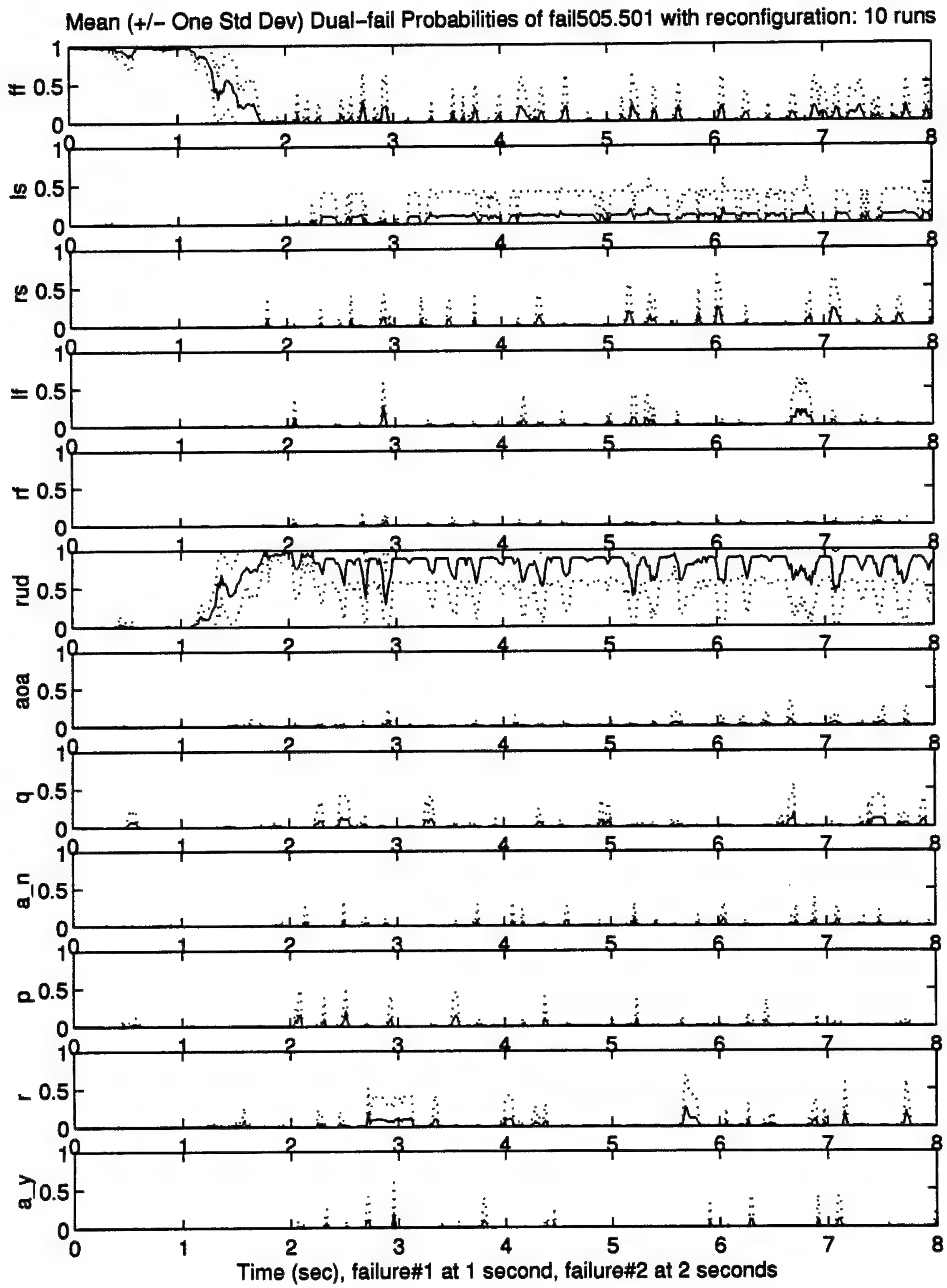

Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



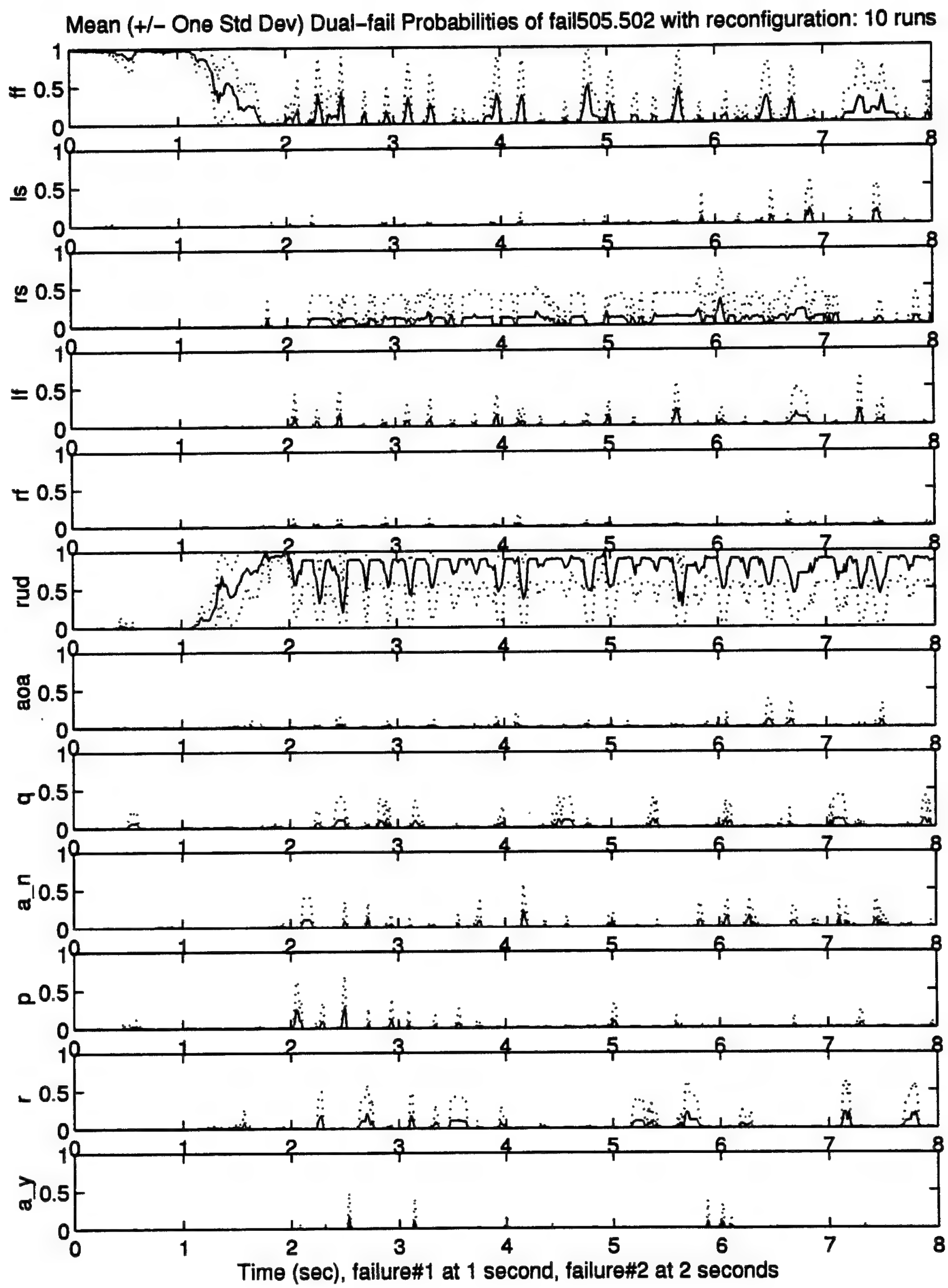
Mean (+/- One Std Dev) Dual-fail Probabilities of fail504.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



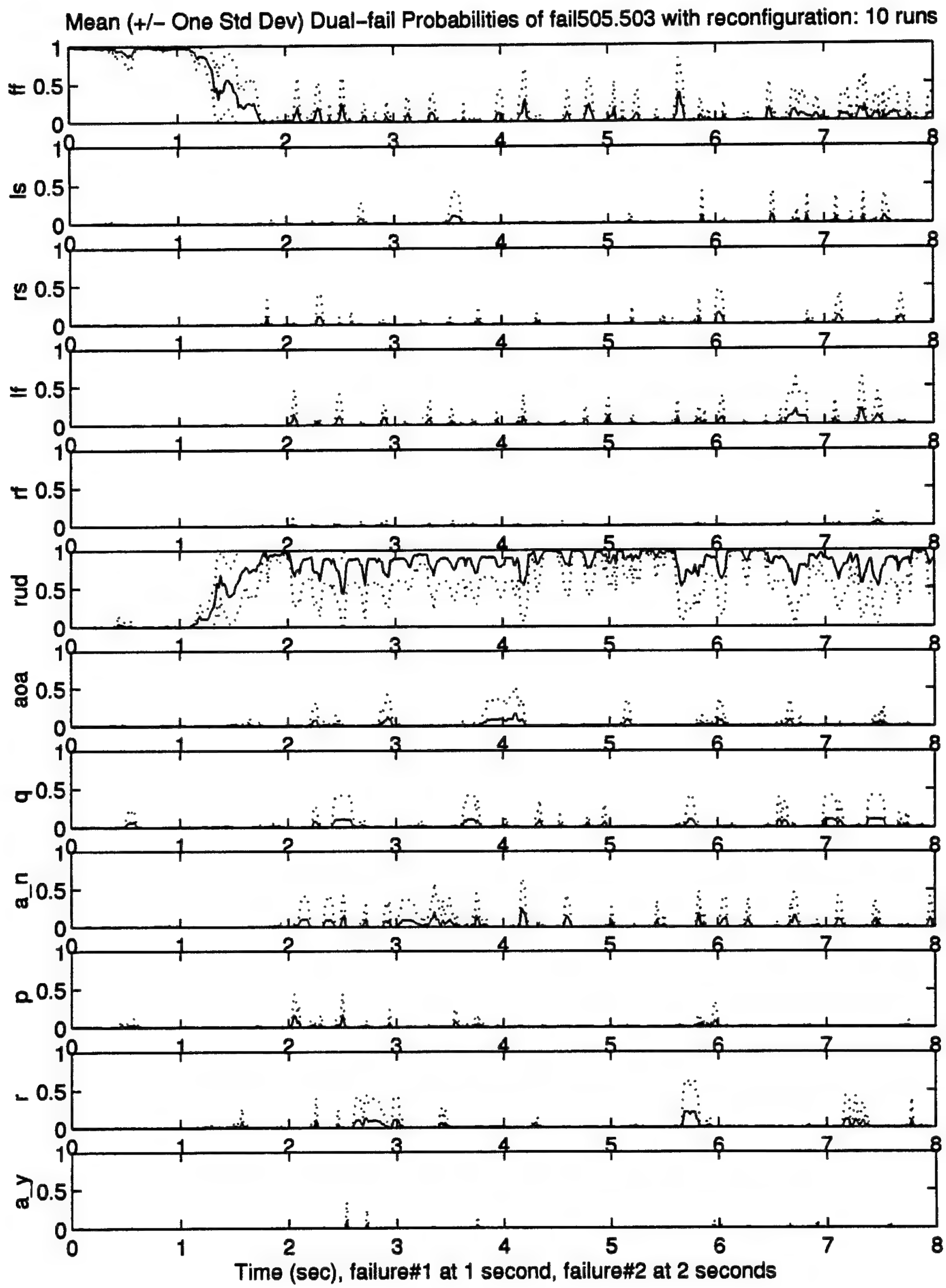
Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.500 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.501 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

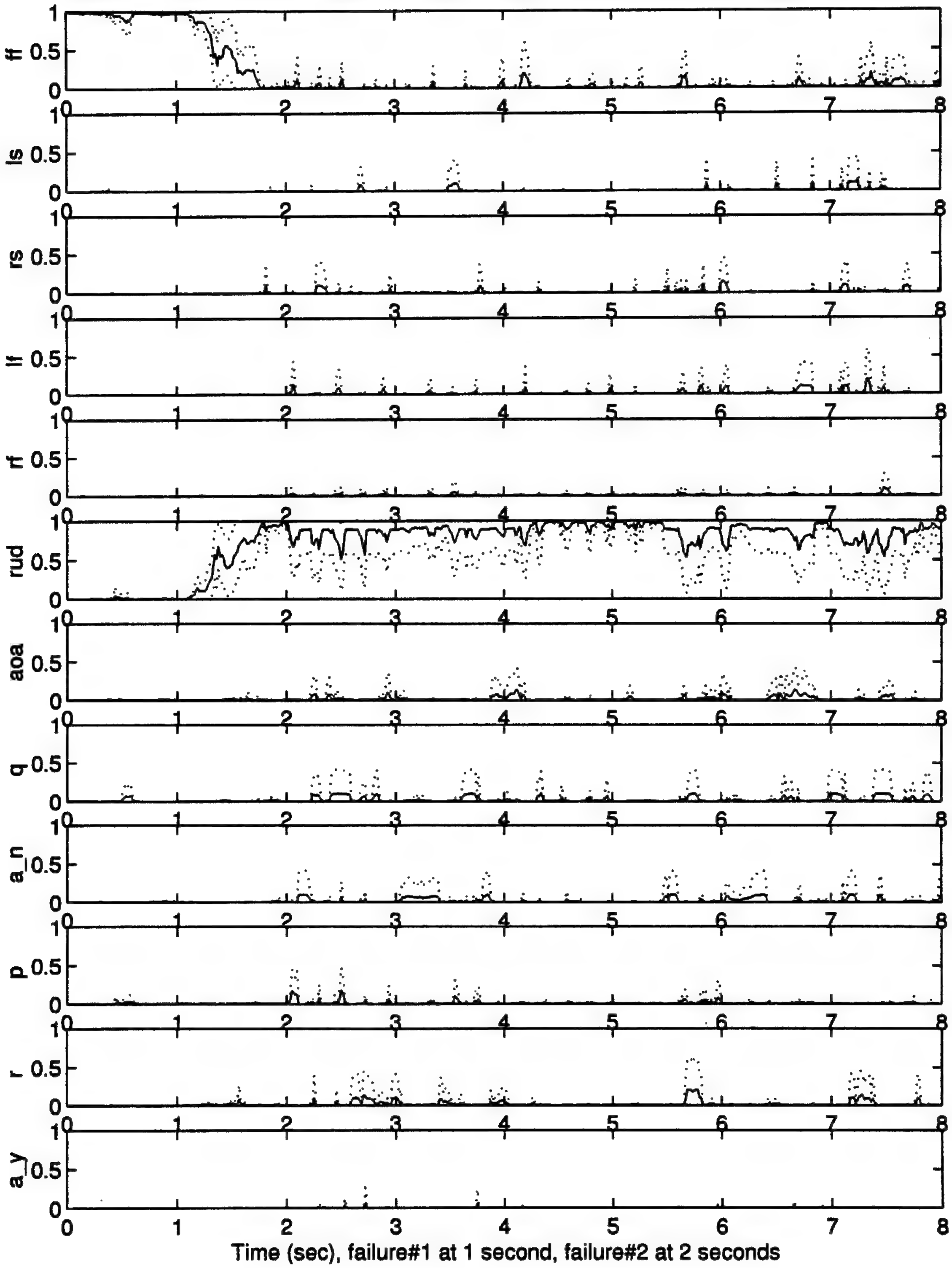


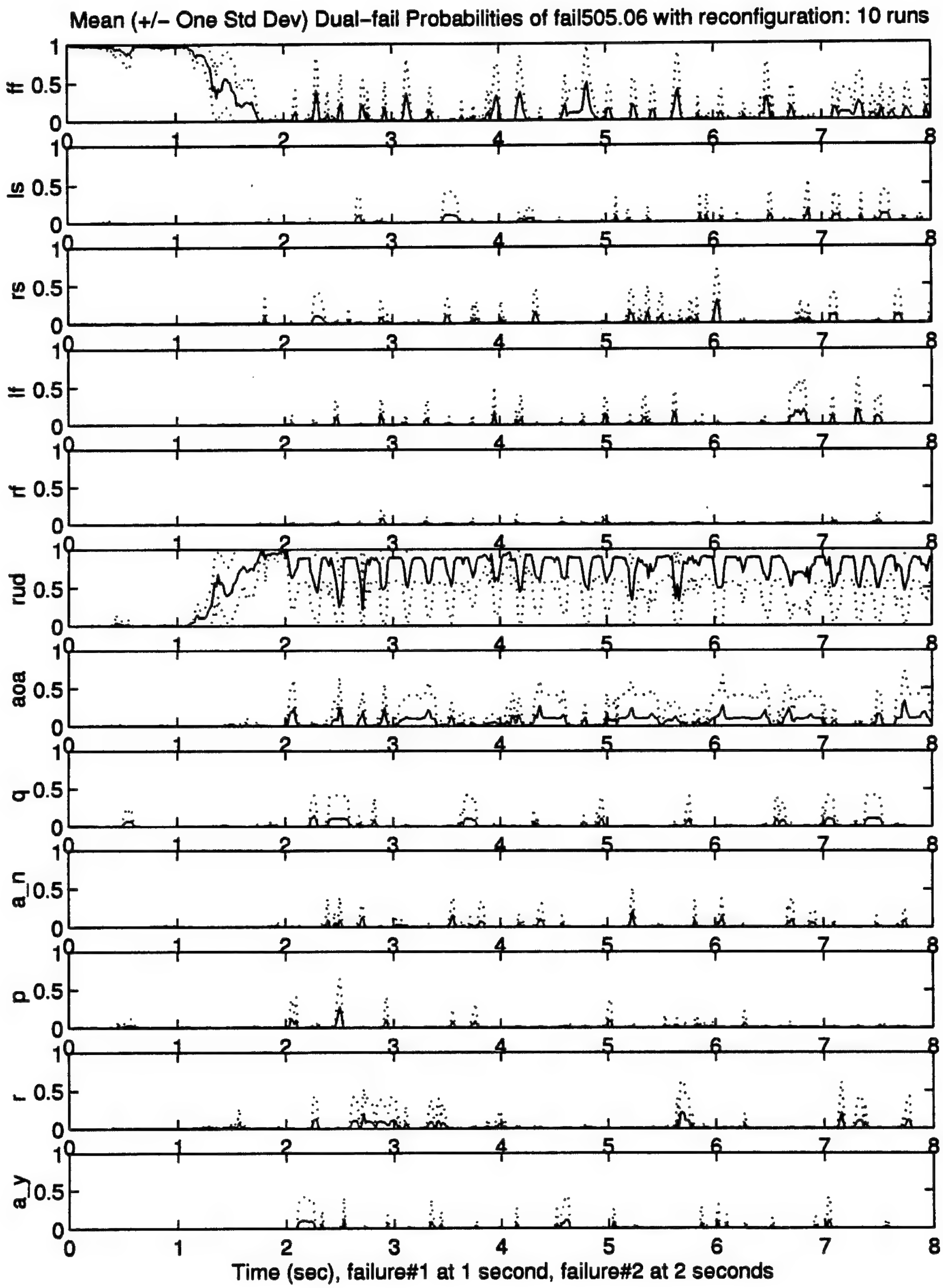
Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.502 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

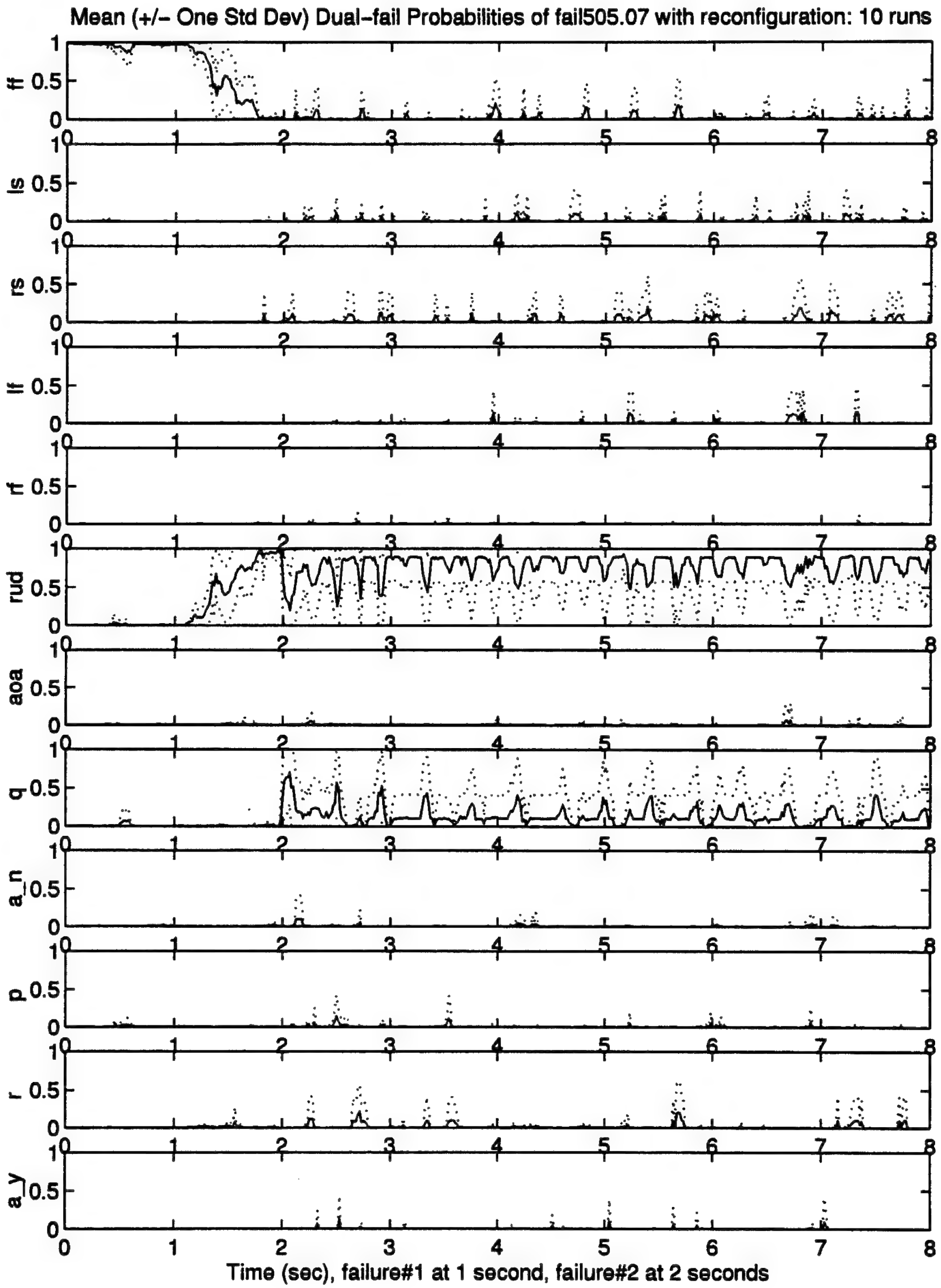


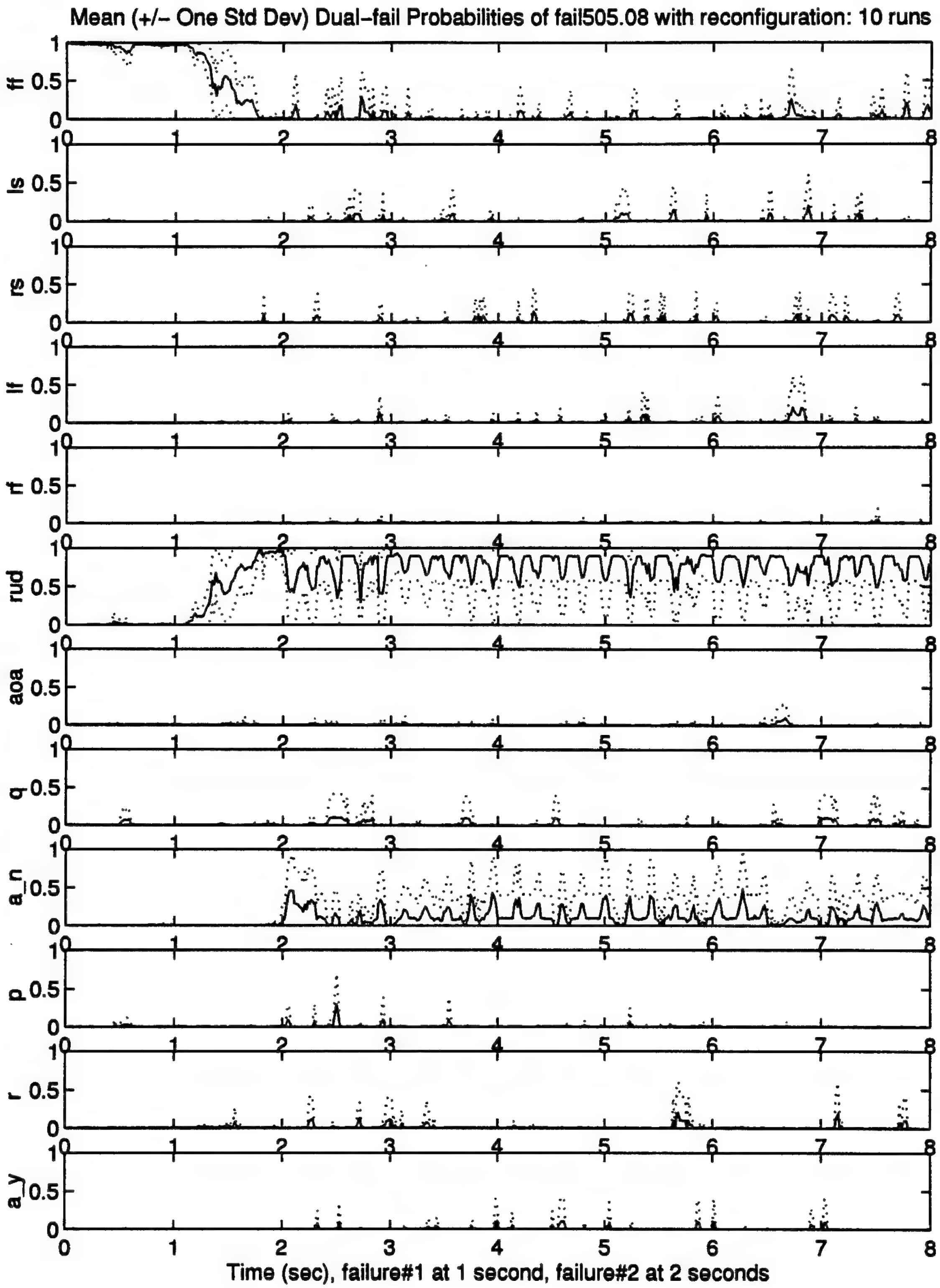
Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.503 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

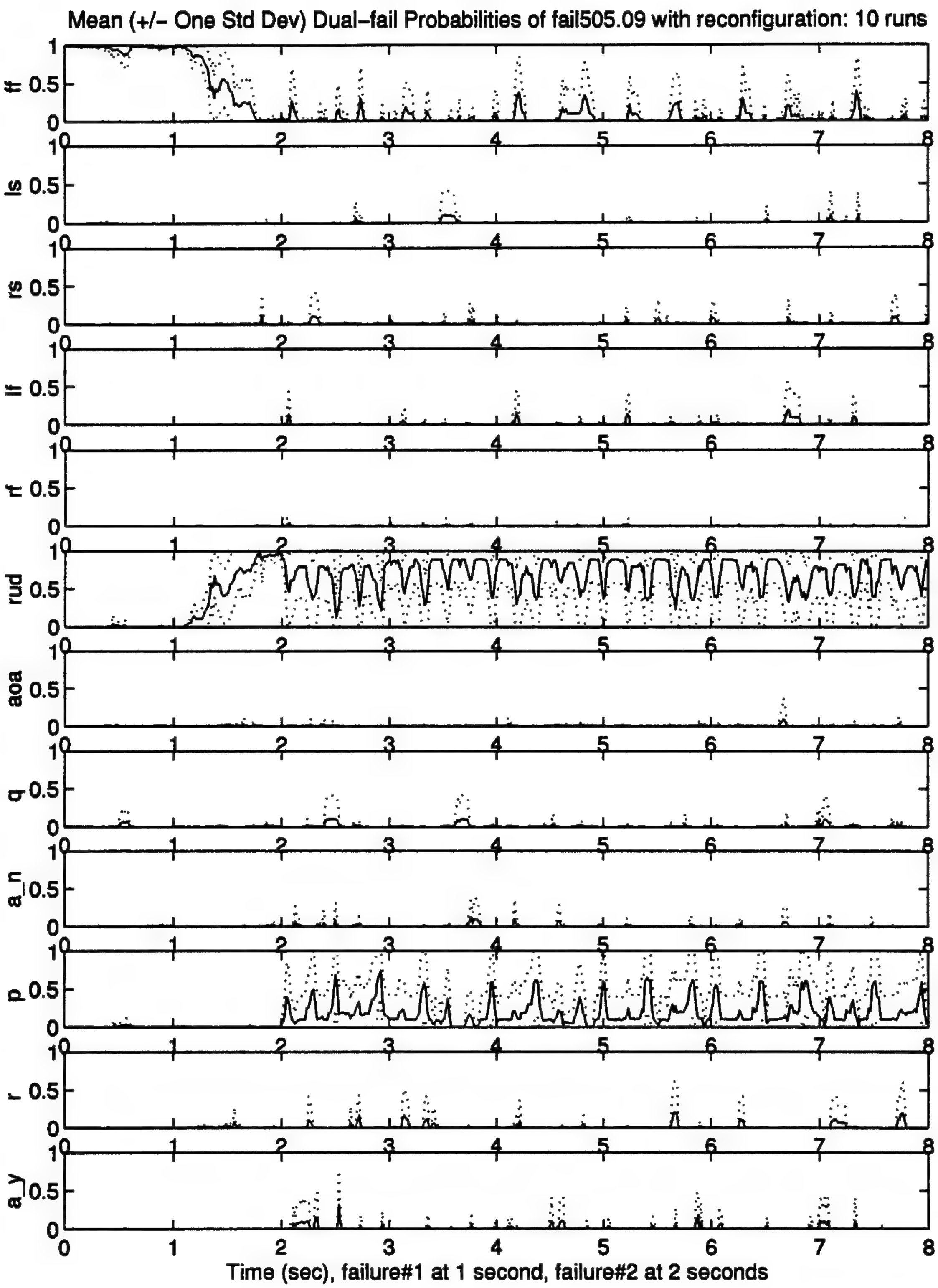
Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.504 with reconfiguration: 10 runs

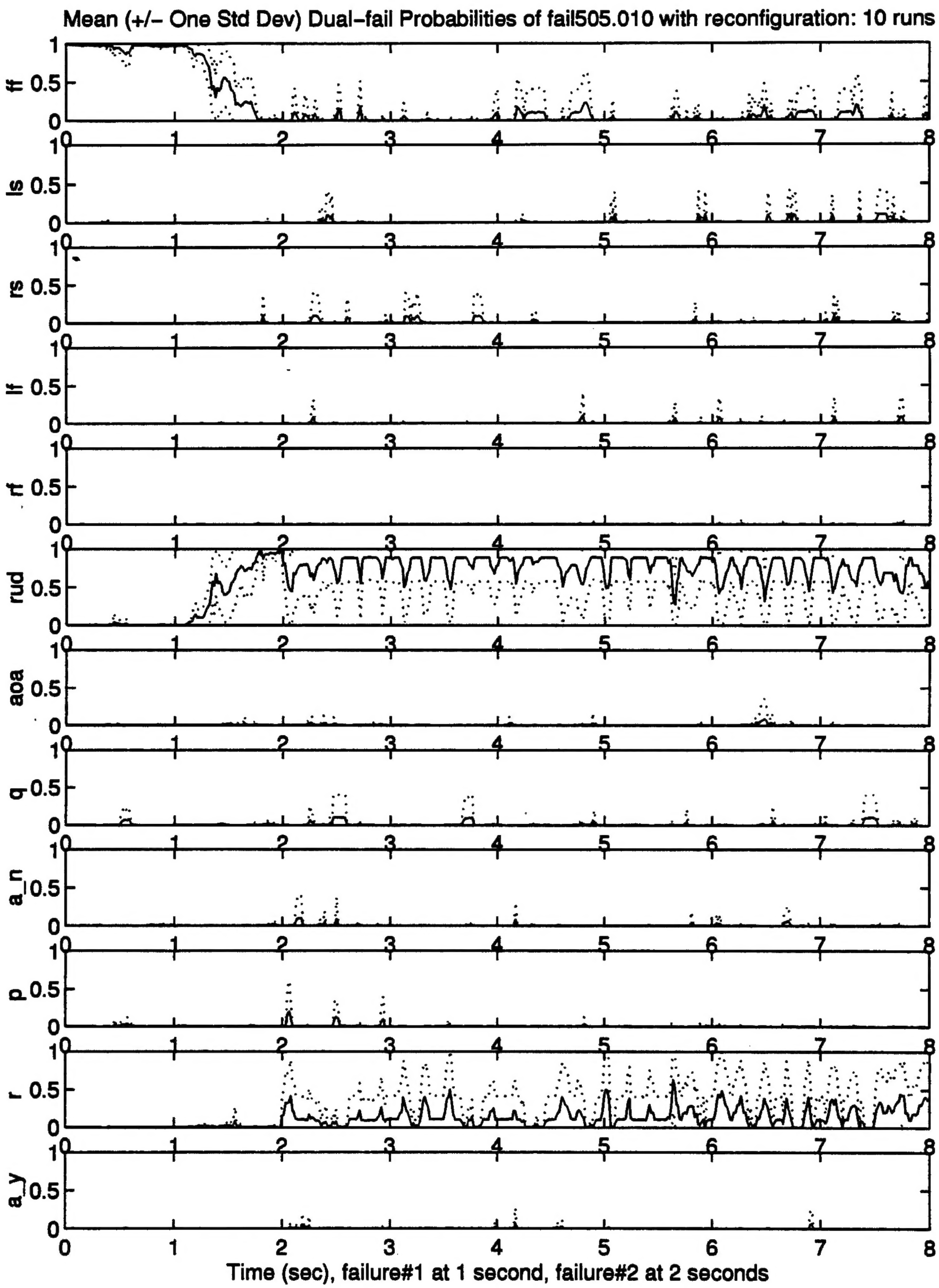


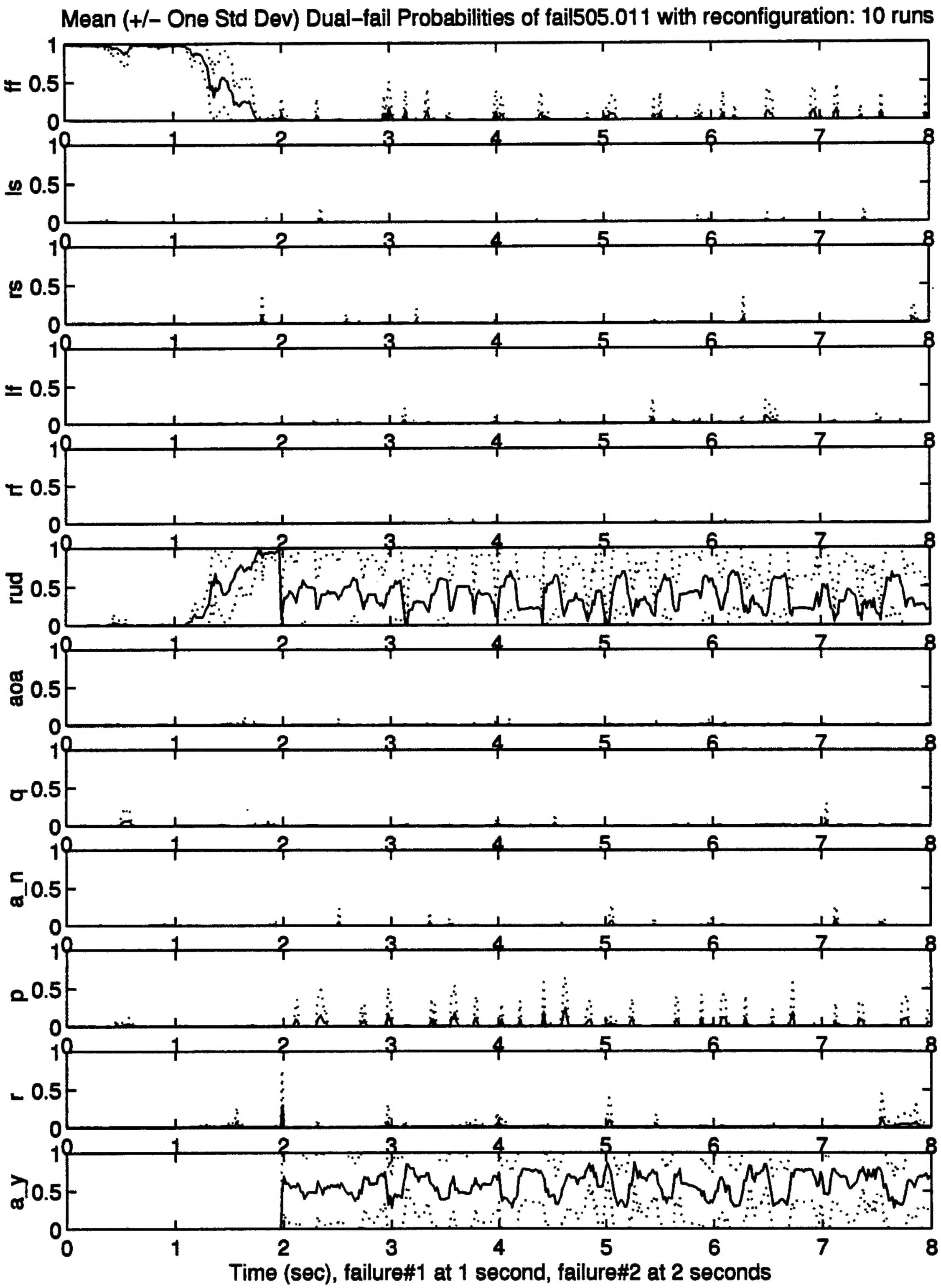

Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.06 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.07 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0 1 2 3 4 5 6 7 8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

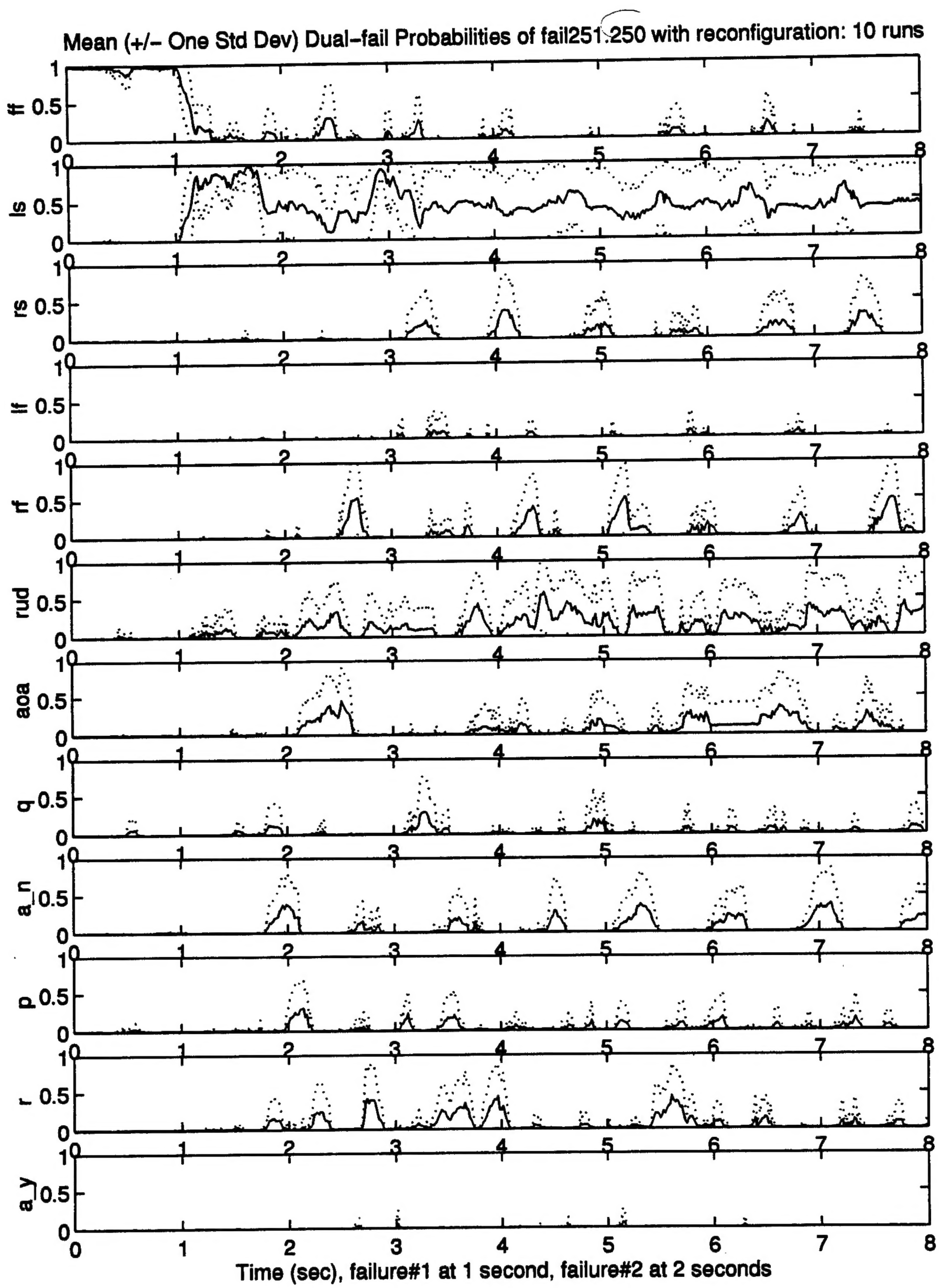

Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.08 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0.5
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.09 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.010 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
0
0.5
1
0
1
2
3
4
5
6
7
8
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds



Mean (+/- One Std Dev) Dual-fail Probabilities of fail505.011 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds


Mean (+/- One Std Dev) Dual-fail Probabilities of fail251.250 with reconfiguration: 10 runs
ff
ls
rs
lf
rf
rud
aoa
q
a_n
p
r
a_y
Time (sec), failure#1 at 1 second, failure#2 at 2 seconds

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13. ABSTRACT *(Maximum 200 words)*
Multiple Model Adaptive Estimation with Control Reconfiguration (MMAE/CR) capability to estimate and compensate for partial actuator failures, or "impairments" is investigated using the high-fidelity, nonlinear, six-degree-of-freedom, VISTA F-16 simulation which currently resides on the Simulation Rapid-Prototyping Facility (SRF). After developing a model for inserting partial actuator impairments into the VISTA F-16 truth model, research begins with a battery of single actuator impairment tests. This stage of research explores the capability of the existing MMAE algorithm to estimate single, partial actuator impairments, and helps to define refinements and expansions needed in the MMAE algorithm for the second phase of research: the detection and estimation of dual, total and partial actuator impairments. It is seen from the first stage of research that, while MMAE is able to estimate partial impairments, there are refinements needed, such as "probability smoothing and quantization", to compensate for the quality of MMAE probability data and to provide a better, more stable estimate value to the Control Reconfiguration module. The Kalman filters and the dual, partial failure filter banks necessary for the detection of dual, partial actuator impairments are also defined as a result of the single impairment tests. Fifteen more banks of "partial first-failure" Kalman filters are added to the existing MMAE algorithm, as well as the "bank swapping" logic necessary to transition to them. Once the revised and expanded MMAE/CR algorithm is ready, research begins on dual combinations of total and partial actuator impairments. While results of these tests (for other than total impairments) are not as good as originally hoped or expected, the potential for better performance is evident.

14. SUBJECT TERMS
Multiple Model Adaptive Estimation, MMAE, Kalman Filter, F-16, Control Reconfiguration, Flight Control, Failure Detection, Reconfigurable Control

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